PN-AAQ-579

Discussion Paper D-73E
ENERGY IN DEVELOPING COUNTRIES SERIES

The Role of Rural Electrification in Development

Elizabeth Cecelski
with Sandra Glatt

A Discussion Paper from the Center for Energy Policy Research
RESOURCES FOR THE FUTURE / WASHINGTON, D.C.

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April 1982

Acknowledgement

The research for this study was funded by the Ford Foundation under Cooperative Agreement No. AID/DSAN-CA-0179 established between Resources for the Future and the U.S. Agency for International Development, Office of Energy (Director, Alan B. Jacobs). Pamela L. Baldwin is the A.I.D. Project Officer for this Cooperative Agreement. The research staff at RFF is headed by William Ramsey, Project Officer and Principal Investigator, and Joy Dunkerley, Co-Principal Investigator. Manuscript preparation was coordinated by Marilyn M. Voigt.

The views expressed in this paper are those of the authors and should not be interpreted as representing the views of either A.I.D. or Resources for the Future.

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Introductory Note

Rural electrification has been the cornerstone of rural energy programs in developing countries. Electricity has provided a safe and efficient energy source for residential and public lighting, pumping drinking water, irrigation, refrigeration, rural industries, and many others. Clearly, rural electrification has been beneficial to developed societies, and most early policy planners felt that the same or similar benefits could be achieved in developing societies.

Recently questions have been raised regarding whether the benefits of rural electrification for a developed society can be duplicated in the developing country context. Low rural incomes may prevent rural families from connecting to the electrification grid. The original assumptions of development planners regarding rural electrification may not necessarily be fulfilled. Because electrification projects involve high capital expenditures, the actual impact of rural electrification in developing countries needs to be evaluated.

"The Role of Rural Electrification in Development," a discussion paper, funded in part by the Rockefeller Foundation, is an analytic review of recent research on rural electrification. Ms. Cecelski reviews important issues involved in rural electrification, including regional and social equity, productive impacts, indirect benefits, and in very general terms the comparative costs of central grid, autogeneration, and alternative energy programs. However, as is the case with most reviews of this kind, in the final chapter the paper raises more questions than answers.

Resources for the Future has made a major commitment to addressing many of the issues presented in this Discussion Paper. One of the major goals of the ARDEN (A.I.D.-RFF Development and ENergy) program, funded by the Agency for International Development under Cooperative Agreement No. AID/DSAN-CA-0179, has been to examine the socioeconomic impacts from, and costs and benefits of rural electrification in developing nations.

Socioeconomic impacts are examined in two major projects, one being carried out in India and the other in Colombia. Both studies evaluate effects on rural productivity and social equity, and investigate conditions complementary to successful outcomes from rural electrification. The analyses will be based on recent field surveys covering over 1500 households in 180 communities.

Costs and some specific economic benefits of rural electrification are examined in other studies in the same two countries, India and Colombia. The purpose of the India study is to determine the corporative subsidy required to extend the central grid to villages with different development profiles. The Colombia study investigates the extent of subsidies involved in rural electrification. Discussion Papers reporting on the above papers will soon be available.

We issue this report on work in progress with the multiple purposes of informing the policy community of the state of knowledge, of stimulating research elsewhere, and of eliciting comments on our own efforts.

Milton Russell
Director
Center for Energy Policy Research

Introduction

Substantial resources have been devoted to rural electrification in developing countries for both economic and social reasons--an estimated $10 billion by 1971 in the nonCommunist regions, with an even larger amount expected to be invested in the next ten years (World Bank, 1975b, p. 3). The provision of electricity in rural areas is widely believed to be a stimulus to increased agricultural productivity and output through irrigation and mechanization, to the growth of rural industries, and to raising the living standards of rural people. In most developing countries, rural electrification is considered important enough to subsidize extensively. The extent of rural electrification is nonetheless not great overall. As table 1 illustrates, about 23 percent of the village--rural population in Latin America, 15 percent in Asia, and 4 percent in Africa south of the Sahara are served by electricity[1] (World Bank, 1975b).

The role of international aid organizations is a key one in this area, both because a significant part of the funds being spent on rural electrification are in the form of loans at concessional rates from these groups, and because much of the technical and planning advice on electrification and other energy alternatives in development of rural areas emerges from these lenders as well. Table 2 indicates the magnitude of participation in rural electrification of the largest concessional lenders.

Rural electrification can be defined as the provision of electricity to areas of low demand and highly dispersed potential consumers. Electricity can be supplied to such areas through small-scale autogeneration, local independent grids, or a central regional or national grid. In this paper, "rural electrification" usually refers to the central grid because most data on impact are based on changes after the introduction of the central grid. In most cases, however, the benefits

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1. "Served" means that the village was connected to a grid, not that its total population was using electricity, so these figures are probably greatly over-estimated. Data from India, for example, indicate that perhaps 10 percent of houses in electrified villages actually have connections.

Table 1. Extent of Rural Electrification, by Region

Region	Population in 1971[a] (millions)			Village-rural population[b,c] served in 1971	
	Total	Village[b]	Rural[b]	Millions	Percentage
			%		
Latin America	282	140	(50)	32	23
Selected countries in Europe, Middle East, and North Africa[d]	143	87	(61)	45	15
Asia	934	700	(75)	105	15
Africa	182	165	(91)	7	4
	1,541	1,092	71	189	12

Note: Electrification data have been compiled from miscellaneous documents and correspondence with countries, and are not official statistics. Population data are from United Nations documents.

Source: World Bank, Rural Electrification: A World Bank Paper (Washington, D.C., World Bank, 1975) p. 17.

[a]Population figures refer to the whole region, except in the case of Europe, Middle East, and North Africa (see footnote d).

[b]The definitions of "village" and "rural" vary between countries. Generally, villages are conglomerations of 5,000 to 10,000 inhabitants or less; rural refers to low-density populations outside the villages, often living in clusters close to large farms.

[c]Electrification data are not available for each country and the percentages should be taken as typical levels for countries in the region, about which there may be considerable variance.

[d]Algeria, Cyprus, Egypt (Arab Republic of), Iran, Morocco, Saudi Arabia, Tunisia, and Turkey.

Table 2. Lending for Rural Electrification by Some International Aid Organizations (U.S. $ millions)

World Bank, 1976-1978

India	57
Egypt	48
Syria	40
Philippines	60
Thailand	25
Total Rural	230
Total Electrification	3,047

Inter-American Development Bank, 1961-1978[a]

	IDB loan	Total cost of projects
Argentina	219	895
Bolivia	174	206
Brazil	1,052	8,079
Chile	90	282
Colombia	415	1,233
Ecuador	170	582
El Salvador	109	386
Regional	394	6,555
Other	665	1,560
Total	3,288	19,778

U.S. Agency for International Development, 1961-78[b]

Africa	0
Asia	278
Latin America	93
Near East	59
Central Funds	405
Total	835

Source: Personal Communication, The World Bank Electricity, Water, & Telecommunications Division, and World Bank, A Program to Accelerate Petroleum Production in the Developing Countries (Washingon, D.C., World Bank, 1979); IDB Annual Report, 1978, and Personal Communication, Energy Section, Infrastructure Division, IDB; and AID, 1978.

[a]Includes total electrification lending.

[b]Excludes two projects in Asia, two in Latin America, and one centrally funded, for which financial data was unavailable.

from using electricity would be similar with autogeneration, in that new electricity-specific services are provided by both autogeneration and the grid. Costs, however, would be different, so a distinction is made between autogeneration and central grid in the section on costs and at other points where it is relevant to do so.

The introduction of electricity through the grid to rural areas is also usually preceded by its use in urban areas and large towns. In one sense, then, "rural" electrification cannot really be separated from electrification in general, because investments in generation and distribution are also investments in future rural electrification.

Historically, the use of electricity has been almost linearly associated with rising incomes and productivity (Guyol, 1969). Today, developing countries with higher per capita incomes typically consume more electricity per capita (Strout, 1977, p. 14) and also devote more investment resources to rural electrification than do poorer countries. Nevertheless, the direction of causation in the relationship between electricity and rural economic development has not been well established. Given that expenditures on rural electrification represent scarce investment resources that could be fruitfully spent in a number of different ways to meet energy or other development needs, the lack of studies examining the causal relationship between rural electrification and socio-economic development is surprising, though less so when one considers the difficulty of the task.

The intent of this paper is to examine in a preliminary way this relationship between rural electrification and economic growth. Given the lack of systematic studies on this topic, any conclusions drawn from previous studies are necessarily tentative and limited: instead, the primary focus is on identifying promising areas for future attention. First, different frameworks of analysis frequently used in evaluating rural electrification projections are reviewed for their usefulness in assessing impacts of electrification on rural economic development. Then, the assumed developmental benefits of rural electrification are compared with evidence from actual projects. Costs of electricity and its most common substitutes--autogeneration in industry, kerosine in household lighting, and diesel engines in irrigation--are examined. Pricing policies and subsidies are discussed; and the effects of availability, reliability, and price of electricity on use, benefits, and production decisions are analyzed. Finally, a preliminary assessment about how rural electrification programs and research should proceed in the future is suggested on the basis of these findings.

Frameworks for Analysis: The State-of-the-Art

Some of the frameworks most commonly used in evaluating the success of rural electrification projects are limited in their usefulness in assessing the impact of rural electrification on economic development. Since these forms of appraisal have largely determined the type of data information which is available about past rural electrification programs, four merit consideration here: (1) meeting "targets" or "forecasts"; (2) financial viability; (3) impact analysis; and (4) benefit-cost analysis.

First, lenders have commonly asked simply: was the project completed? Were the required number of miles of power lines constructed within the allotted time period, the funds spent in the prescribed way, etc.? In national rural electrification projects, a variation of this theme is whether targets in the rural electrification scheme have been met: number of villages electrified, pumpset connections "released," kilowatt hours sold.[2]

The use of targets is a good means of checking success in construction, forecasting, and promotion of use, especially if targets are set carefully. Presumably the yearly targets are the load forecast upon some reasonable assumptions about the unsatisfied effective demand for electricity that exists or will exist in the countryside. But in many cases targets instead appear to represent the minimum load levels required to make a project financially viable. Table 3 shows the extent to which targets for village electrification have been achieved in some areas of India: in most cases connections and number of villages electrified have fallen short of expectations.

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2. See, for example, CMA, 1974; Sen Lalit, 1974; and Sen Gupta, 1977.

Table 3. Percentage Achieved of Forecast Targets for Rural Electrification in Selected Areas of India (% of forecast targets)

	Madhya Pradesh		Uttar Pradesh		Andhra Pradesh		Gujarat		
	Pench	Depalpur	Modinagar	Chandauli	Kurnool	Telangana	Una	Bayad-Modasa	Kodinar
Villages electrified	86	203	91	29	54	97	85	65	42
Pumpset connections	63	14	127	44	30	37	18	13	20
Rural industries	387	92	28	15	16	22	37	56	58
Domestic/Commercial	81	19	9	0.4	-	15	38	42	68
Street lights	174	163	15	0.2	-	54	2	38	-

Sources: National Council of Applied Economic Research (NCAER), Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977) pp. 4-5 and Perspective Plan for Rural Electrification in the Telangana Region of Andhra Pradesh (1975-76 to 1988-89) (New Delhi NCAER, May 1978) pp. 444-445; Shreekaut, Sambrani, Gunvant M. Desai, V. K. Gupta and P. M. Shingi, Electrification in Rural Gujarat: Vol. I Kodinar Rural Electricity Cooperative Ltd., Vol. II Una Scheme; Vol. III Bayad-Modasa (Ahmedabad, Center for Management in Agriculture, October 1974); Small Industry Extension Training Institute (SIETI), Impact of Electrification on Rural Industrial Development: A Study in Kurnool District, Andhra Pradesh (Yousufguda, Hyderabad, SIETI, 1976) p. 108.

A second and somewhat more useful approach for these purposes is rating the success of a rural electrification project in terms of its financial viability.[3] Since social benefits and costs are excluded from the calculations, this approach is still insufficient: but financial viability indicating willingness-to-pay on the part of consumers does provide a direct if imperfect measure of some benefits from the project and a presumption of a positive economic rate of return. A project lacking financial viability may still have a positive economic rate of return, however, since uncounted social benefits will almost always outweigh the uncounted social costs.

The use of financial viability or completion of agreed construction as criteria for success is an understandable approach on the part of lenders, who will be concerned that they be repaid in a timely fashion, and that the power sector be insulated from political pressures in other parts of the government. Few developing country utilities appear isolated from political considerations, however; indeed, if rural electrification is to be an effective part of a development program, politics are probably important for determining the goals of electrification policy. Some authors have argued that international lenders should accept this political aspect of rural electrification programs and determine how best to achieve efficiency goals in the power sector within this framework (Tendler, 1978; McCawley, 1979).

A third way of evaluating rural electrification projects is to ascertain its impact on users: what changed after electrification? This approach can assume various levels of sophistication, from just listing potential benefits that might result from electrification, to quantifying concrete changes in output pre- and post-electrification, and finally to attempting to establish an actual causal linkage between electrification and certain results.[4] The evaluation of impacts of infrastructure projects such as electrification, roads, and telecommunications is different from that of most other projects in that the outputs of infrastructure

3. See, for example, NRECA, 1974.

4. See, for example, respectively, NRECA, 1978; Davis, 1973; and NCAER, 1977.

projects are often difficult to define and measure. This is particularly true in attempting to analyze the impact of rural electrification on economic development, since the primary interest here is not the direct output--electricity--but the more indirect changes in production and lifestyles which result from its use.

Another problem is the need to know both the "before" and "after" situation in order to measure impacts accurately. Besides all the difficulties normally associated with consumer surveys in developing countries and among the poor, surveys made prior to electrification can only ask for approximations of intended use, while those carried out afterwards must rely upon the memory of users as to energy consumption and prices. Furthermore, while some direct effects, such as cost savings over alternative fuels, are relatively easy to attribute to electrification, others, such as changes in productivity, are not; and indirect benefits such as environmental improvement are even more difficult to assign. Then too, many effects will only become evident years after the project has been completed. Thus, impact analysis, while satisfactory in many respects--if these measurement problems can be solved--still only takes into consideration the benefits while ignoring the costs of rural electrification.

A fourth approach to evaluating these effects is benefit-cost analysis. Since investment resources in developing countries are scarce and have many competing uses, ideally all social costs and benefits should be valued in money terms, and net benefits of rural electrification projects calculated and compared with the net benefits of other uses for capital. Benefit-cost analysis seems the most appropriate framework of the four described above to use for getting at the role of rural electrification in development. It is thus perhaps surprising, at first glance, that this approach has been so rarely used in the evaluation of rural electrification programs. One obvious reason for this neglect is the difficulty of determining and measuring impacts and linkages, as discussed above.

This review will adopt benefit-cost framework as a point of view for examining rural electrification. This framework will be an exceedingly broad one, including both direct and indirect effects--at least in theory.

Usually, of course, the data from past rural electrification projects will only support a qualitative or anecdotal valuation of impacts, and the structure of the costs is also usually not transparent.

Benefits from Electrification

Sectoral Consumption

Before examining benefits from rural electrification in detail, it is useful to get an overall impression of how electricity consumption is distributed among sectors of the economy and the quantities that are consumed. First, it should be realized that the quantities of electricity consumed in rural areas tend to be very small, both in the aggregate and per consumer, as compared to urban areas--less than one fourth of urban levels, according to World Bank figures (World Bank, 1975b, pp. 25-26). For example, 90 percent of connected rural households in a surveyed area of the Philippines where rural electrification is considered highly successful used less than 35 kilowatt-hours of electricity a month--about enough to use two 100-watt light bulbs for four hours a day (USAID, 1976, p. 150).

Second, the weight of different sectors in total rural area electricity consumption varies enormously. Table 4 shows the residential-commercial share being quite high--about 25 to 60 percent in the surveyed areas of most countries--with the notable exceptions of India and parts of Nicaragua, where agricultural or industrial uses predominate and consume most of the total in some rural areas. It is not clear the extent to which this distribution reflects the desire for electricity in these areas, however, or different types of agriculture. In some cases, this sectoral distribution appears to have been a result of policy: in the Philippines, a promotional campaign has emphasized households, and in India, irrigation has been put at the forefront of electrification.

Interestingly, the distribution of these uses appears to change little over time in most cases (see table 5) although the establishment of industry with a large load (many industries have higher consumption levels than an entire village of residential consumers) can make a big difference in a short period. In the Philippines, for example, the share of the large commercial and industrial sector rose from 3 percent to 23 percent of total consumption in only three years (see table 5). But in the other areas

Table 4. Electricity Consumption by Sector in Some Rural Areas (% of kWh consumed)

	Residential (1)	Commercial (2)	Industrial (3)	Irrigation (4)	All Productive Uses (2)+(3)+(4)	Other[a]	Total
Costa Rica (1973)	30	22	45	--	67	3	100
El Salvador (1972)	36	24	34[c]	2	60	4	100
Nicaragua (1976)							
COERAM	30	--	2[e]	60	62	8	100
CODERSE	26	4[d]	55[e]	4	63	11	100
CAEER	54	6[d]	18[e]	2	26	20	100
India							
Telangana, A.P. (1975-76)	21	12	17	48	77	2	100
Suryapet, A.P. (1971)[b]	6	1	4	88	93	1	100
Una, Gujarat (1973)	13	13	7	79	86	1	100
Bayad-Modasa, Gujarat (1973)	18	18	23	54	--	5	100
Indonesia (1974-75)	69	--	3	--	3	28	100
Philippines (1975-76)							
Camarines Sur I	59	29	--	1	30	11	100
Albay Ccop.	64[f]	21	4	--	25	11	100
Misamis Oriental	44[g]	16	23[h]	2	41	15	100
Thailand, PEA (1972)	30	34[i]	33[j]	--	67	3	100

Sources: Ross, James E., Cooperative Rural Electrification: Case Studies of Pilot Projects in Latin America (New York, Praeger, 1972); Davis, J. Michael, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification: An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia, report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D.C., World Bank, 1975); McCawley, Peter, "Rural Electrification in Indonesia--Is it Time?" Bulletin of Indonesian Economic Studies (1979); Developing Alternatives, Inc., An Evaluation of the Program Performance of the International Program Division of the National Rural Electric Cooperative Association (NRECA), report to U.S. AID (Washington, D.C., DAI, January 28, 1977); U.S. Agency for International Development (USAID), An Evaluation Study of the Misamis Oriental Electric Service Cooperative (Manila, USAID, 1976); Turvey, Ralph and Dennis Anderson, Electricity Economics: Essays and Case Studies (Baltimore, Johns Hopkins University Press for the World Bank, 1977); National Council of Applied Economic Research, Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977); Sen, Lalit K. and Girish K. Misra, Regional Planning for Rural Electrification. A Case Study in Suryapet Taluk, Nalgonda District, Andhra Pradesh (Hyderabad, National Institute of Community Development, 1974); Sambrani, Shreekaut, Gunvant M. Desai, V. K. Gupta and P. M. Shingi, Electrification in Rural Gujarat: Vol. I, Kodinar Rural Electricity Cooperative Ltd; Vol. II Una Scheme; Vol. III Bayad-Modasa (Ahmedabad, Center for Management in Agriculture, October 1974); and Moon, Gilbert and National Rural Electric Cooperative Association (NRECA), Report on Rural Electrification Costs, Benefits, Usages, Issues and Developments in Five Countries (Washington, D.C., NRECA, 1974).

[a] Includes street lights, government offices, public buildings, water pumps and systems, and own use by plant.

[b] Percent connected load.

[c] LV 14 and HV motive power 20.

[d] Small business and industry.

[e] Large business and industry.

[f] Problacions 31.5, barrios 32.5.

[g] Problacions 21, rural 23.

[h] Small 18.0, medium 3.3.

[i] Small business 16, general business 12, medium business 6.

[j] Large business and mining.

Table 5. Changes in the Sectoral Distribution of Electricity Consumption Over Time in Some Rural Areas (% of total kWh)

	Year					
	1[a]	2	3	4	5	6
El Salvador						
Domestic	40					36
General	27					24
Motive Power	23					34
Ir~igation	2					2
Public Lighting	8					4
	100					
Thailand						
Households	35				30	
Business						
Small	13				16	
General	17				12	
Medium	2				6	
Large	10				30	
Mining	20				3	
Irrigation	-				-	
Waterworks	2				2	
	100				100	
Philippines (Misamis)						
Residential						
poblacions	26	22	23	21		
rural	27	24	24	23		
Public buildings	7	4	4	4		
Commercial						
small	26	22	21	16		
large & Industrial	3	13	15	23		
Irrigation	-	2	2	2		
Water System	1	3	3	5		
Public Lighting	10	10	8	6		
	100	100	100	100		
Telangana, A.P., India						
Residential	20	20	19	19	21	
Commercial	15	14	13	12	12	
Industrial	16	16	16	16	17	
Irrigation	44	47	49	51	48	
Other	4	3	3	2	2	
	100	100	100	100	100	
Una, Gujarat, India						
Residential[b]	16	14	13			
Industrial	7	13	7			
Irrigation	77	73	79			
	100	100	100			

Table 5 continued

Bayad-Modasa, Gujarat, India				
Residential[b]	12	21	24	18
Industrial	81	54	25	23
Irrigation	4	21	46	54
Other	3	4	5	5
	100	100	100	100

Sources: Ross, James E., Cooperative Rural Electrification: Case Studies of Pilot Projects in Latin America (New York, Praeger, 1972); Davis, J. Michael, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification, An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia, report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P.U. Res. 5 (Washington, D.C., World Bank, 1975); McCawley, Peter, "Rural Electrification in Indonesia--Is it Time?" Bulletin of Indonesian Economic Studies (1979); Developing Alternatives, Inc., An Evaluation of the Program Performance of the International Program Division of the National Rural Electric Cooperative Association (NRECA), report to U.S. Agency for International Development (Washington, D.C., DAI, January 28, 1977); U.S. Agency for International Development (USAID), An Evaluative Study of the Misamis Oriental Electric Service Cooperative (Manila, USAID, 1976); Turvey, Ralph and Dennis Anderson, Electricity Economics: Essays and Case Studies (Baltimore, Johns Hopkins University Press for the World Bank, 1977); National Council of Applied Economic Research, Perspective Plan for Rural Electrification in the Telangana Region of Andhra Pradesh (1975-76 to 1988-89) (New Delhi, NCAER, May 1978); Sen Lalit K. and Girish K. Misra, Regional Planning for Rural Electrification. A Case Study in Suryapet Taluk, Nalgonda District, Andhra Pradesh (Hyderabad, National Institute of Community Development, 1974); Sambrani, Shreekaut, Gunvant M. Desai, V. K. Gupta and P. M. Shingi, Electrification in Rural Gujarat: Vol. I, Kodinar Rural Electricity Cooperative Ltd; Vol. II Una Scheme; Vol. III Bayad-Modasa (Amhedabad, Center for Management in Agriculture, October 1974); and Moon, Gilbert and National Rural Electric Cooperative Association (NRECA), Report on Rural Electrification Costs, Benefits, Usages, Issues and Developments in Five Countries (Washington, D.C., NRECA, 1974).

[a]In most but not all cases, year one is the first year after electrification.

[b]Includes commercial.

surveyed here, sectoral shares of consumption of electricity have generally remained relatively stable.

Benefits

While ultimately desirable to arrive at a measure of net benefits in terms of economic development due to electrification, it is simpler first to view gross benefits assumed to result from rural electrification, and compare these assumed benefits with evidence from projects, without explicitly considering costs. Developmental benefits often cited as potentially or possibly due to rural electrification are numerous, as can be seen from table 6. This myriad of benefits have rarely been tested empirically, however, and quantitative evidence of their importance or indeed their existence is difficult to find. One review has gone so far as to conclude that "the more objective the study and the more thorough the data collection and analysis techniques, the fewer benefits can be attributed to rural electrification." (DAI, 1977, p. 84). A difficulty here is that some of the most important assumed benefits are the hardest to measure, as discussed above. Another related problem is that detailed studies over long periods of time would be needed to capture all benefits, and effects become more difficult to assign to causes as time passes. Here, both direct benefits to households, agriculture, and industry; and indirect benefits in terms of social and public uses, employment, environmental improvements, foreign exchange savings, demographic changes, political stability, and modernization, will be considered, in at least a qualitative and whenever possible, a quantitative way.

Direct Benefits

In theory, direct benefits to users of electric power are of three sorts. First, electricity may cost less than alternatives providing the same energy services; electric pumps may be cheaper than diesel. Second, electricity may allow the performance of entirely new tasks, or may perform the same tasks so much more efficiently than other energy sources that they are actually qualitatively new tasks. Where television and improved lighting become available with electrification, new or higher quality services are achieved. In addition, the availability of cheaper energy or this ability to perform essentially new tasks can result in more energy

Table 6. Potential Benefits From Rural Electrification

Few would disagree that one of the most significant differences between the developing nations of the world and those in which people enjoy healthy, productive lives is the establishment and widespread use of effective electric power systems. Since 1961 NRECA's International Programs Division has provided management consulting services and technical assistance to the Agency for International Development of the U.S. Department of State and to other international agencies and institutions involved with the planning and development of feasible rural electric distribution systems in countries throughout the world. IPD assistance has been utilized in 33 countries to establish or improve rural electrification programs, and over four million people are now benefiting from this assistance. The following list of 50 indicators of social and economic benefits demonstrates that rural electrification, as part of a rural development program, can introduce immediate and tangible benefits to the rural population, especially the rural poor.

1. Irrigation systems utilizing electric system equipment, tube wells, etc., allowing for multiple cropping.

2. Property formulated livestock and poultry feeds prepared in small mills.

3. Automated poultry processing/breeding systems.

4. Refrigeration of perishable farm agricultural products and utilization of milk coolers.

5. Electrically powered grain drying, processing, storage systems and fumigation.

6. Conservation of export quality timber (electricity replaces wood for cooking and heating).

7. Fish farms in areas where pumps required.

8. Working through his Cooperative provides farmer with some degree of leverage in the marketplace.

9. Agriculture employment opportunities generated.

10. Electrically powered handicraft industries allowing for varied and increased production. (Cottage or home produced items can be made during off peak seasons of agricultural cycles).

11. Employment opportunities, especially for women, in commercial nonagricultural industries. (Due to electricity, women with reduced homemaking chores are able to earn much needed extra income either on full-time or part-time basis).

12. Market/stores utilizing refrigeration. Decrease in spoilage of perishables, especially in tropical areas.

13. Development of small industries to meet created demand for simple electric appliances.

14. Development of industries supplying poles, cross arms, insulators, hardware, meters and transformers for electric distribution systems.

15. Employment opportunities created by Cooperatives, contractors, National Electrification Administration, auditing and accounting firms.

16. Limited school facilities utilized for night classes.

17. Community facilities such as libraries opened in evenings.

18. Wider use of audio visual equipment and materials in schools and adult education programs.

19. Allows for home economics training for women utilizing sewing machines and home appliances.

20. Women's routine home chores eased, which allows for daughters to be freer to attend school.

21. Lighted outdoor athletic facilities such as basketball courts allows for community recreation. (Too hot in tropical countries to participate during daytime.)

22. Teachers more productive and better prepared due to home lighting.

23. Students academically improve. Homework better prepared.

24. Refrigeration of medical supplies by clinics and hospitals.

25. Use of sterilizers and electrical detection equipment in rural clinics.

26. Reliable source of power for hospitals and operating rooms.

27. Home electrical appliances allow for sanitary preparation of food and water. Electric pumps provide potable water.

28. Home refrigeration prevents spoilage of perishable foods adn reduces health hazards.

29. Restaurants utilizing electrical appliances and refrigeration reduce health hazards.

30. Correlation of home lighting and decrease in population growth rate.

31. Increased security due to night lighting. Crime rate decreases.

32. Lighted homes provide social benefits.

33. Utilization of radio and television for education, entertainment and leisure.

34. Appliances such as irons, hot plates, simple washing machines reduce work burden for women.

35. New home construction and improvement results from electrification.

36. Cooperatives provide outlet for community and national participation by rural population. Provides experience in management and democratic decision-making.

37. Improved and increased craft production in addition to economic benefits, enhances the cultural and aesthetic values that craftsmen and crafts tradition mean to a nation (national pride).

38. Cooperative institution, organization and facilities utilized for members' services (Better Family Living) such as family planning, crafts, home economics.

39. Change in social well being. Index of satisfaction with one's current situation improves. New confidence.

40. Keeps the economic proceeds of a region invested locally.

41. Accelerates the monetization of the rural society.

42. Stems rural migration to cities and improves rural-urban balance. Increased rural economic activity absorbs expanding rural labor force.

43. Decentralizes economic activity.

44. Rural population participating in a "self-problem solving" climate rather than a "depending on the government" climate.

45. Increased net tax revenues to government.

46. Leveling of ethnic differences.

47. Improved citizens-government relationship.

48. Reduced socioeconomic imbalance in the population.

49. Expanded communications system to entire population. Government able to communicate with its citizens.

50. Reduced foreign exchange expenditures for kerosine and oil used for lighting, cooking and heating. (A central generator is a much more efficient method for supplying energy, rather than each household purchasing fuel.)

Source: National Rural Electric Cooperative (NRECA) "Social and Economic Benefits of Rural Electrification Cooperatives" (Washington, D.C., 1978).

being used and in new production being undertaken, adding value in other areas--more irrigation resulting in more agricultural output, for example, or new processes being used in rural industry (Selowsky, 1975).

It is important to keep in mind, however, that the demand for electricity is a derived demand; the demand for electricity for pumps is a result of the demand for irrigation; the demand for electricity for motive power in small industries derives from demand for their products; the demand for lighting could result from demands for education, necessitating reading at night, etc. Thus, the benefits obtainable from electrification will depend equally upon complementary investment devisions and inputs, availability of credit for necessary electricity using devices, the existence of transport, schools and other infrastructure, government information services, and so on.

Benefits from electrification may be reaped by (1) households, (2) farms, and (3) industry. With respect to social and public uses of electricity, some of the benefits may be direct and others indirect; for convenience, these have been treated in the following section on indirect benefits.

Households. Direct benefits to households are presumably present if consumers choose to use electricity--since a household would not allocate funds to purchase electricity unless it provided a lower cost or higher quality services. Thus the extent of use is an important measure of direct benefits to households. The data support four generalizations: (1) average consumption per household is very low, but rates of growth can be high; (2) more advanced and larger areas tend to be more electrified than smaller and more backward ones; (3) the rather small percentages of households that are connected have relatively higher incomes than unelectrified households; and (4) appliance ownership is the single most important determinant of electricity consumption and its growth.

Average consumption per household. While average consumption per household are very low, rates of growth can be high. This is clear from table 7, which shows average annual consumption of electricity by residential consumers is low but varies greatly, from a very low number of kilowatt-hours a month in the Philippines, to greater than early U.S. rural levels in Costa Rica. Growth in consumption also appears to proceed quite rapidly in many cases, with annual growth rates of over 50 percent at times.

Table 7. Average Annual Electricity Consumption Per Residential Consumer, and Growth Rates, Selected Rural Areas

	1	2		3		4		5	
	kWh	kWh	% Change	kWh	% Change	kWh	% Change	kWh	% Change
Costa Rica (1970-1973)	607	630	4%	697	11%	717	3%	--	--
Nicaragua (1968-73)	414	370	-11%	400	8%	411	3%	429	4%
El Salvador (1963-67)[a]	419	463	11%	1086	134%	602	-45%	940	56%
Philippines (1972-75)									
poblacion	29	28	-4%	36	29%	40	11%	--	--
rural	23	20	-13%	22	10%	24	9%		
United States (1941)[b]	600								

Sources: U. S. Department of Agriculture Rural Electrification 1972 Rural Lines: The Story of Cooperative Rural Electrification (Washington, D.C. GPO, 1972); Moon, Gilbert and National Rural Electric Cooperative Association (NRECA), Report on Rural Electrification Costs, Benefits, Usages, Issues and Developments in Five Countries (Washington, D.C., NRECA, 1974, p. 12 and p. 46); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D.C., World Bank, 1975); and U.S. Agency for International Development (USAID), An Evaluative Study of the Misamis Oriental Electric Service Cooperative (Manila, USAID, 1976, p. 158 of 198 Annex L).

[a]All users.

[b]Includes farms.

Distribution of Benefits: Size of Population Centers. More advanced and larger areas tend to be more electrified than smaller and more backward ones; table 8 shows the percent of electrified localities by population size in Andhra Pradesh, one of the most advanced Indian states in rural electrification; clearly, larger population centers are more electrified than smaller ones. Other studies have shown larger and more advanced areas, not surprisingly, to be more electrified as well (see, for example, NCAER, 1978, p. 84; Sen Lalit, 1974, p. 107; Selowsky, 1976).[5] The average number of connections in some "electrified" Indian villages has been reported as low as 10 or 12 (SIETI, 1976, p. 167; Sen Lalit, 1974, p. 112). Punjab is claimed as a completely electrified state for example, but reportedly only 30 percent of its population actually has access to electricity (Ramsay, 1979, p. 20). In rural Suryapet, an average of only 3.5 percent of the houses in electrified villages use electricity; in Karnataka the figure is 8 - 10 percent (Sen Lalit, 1974, p. 109; Sen Gupta, 1977, p. 29).

These figures for India, where electrification investment has been spread widely rather than deeply, are probably lower than for some other countries. In a surveyed rural area of the Philippines, 28 to 34 percent of all households were electrified (though 54 to 74 percent had access to electricity--in other words, could have received a connection had they so desired) (NEA, 1978, p. 19). In Nicaragua, an informal survey revealed that fewer than half of rural households with access to electricity had connected (DAI, 1977, p. B-16).

There is of course, nothing wrong in itself with only larger villages being electrified--in fact, economically this undoubtedly makes sense. Nor is there necessarily anything wrong with only some households who desire it receiving electricity, particularly if this contributes to building up an

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5. It is worth noting here that "electrified" in Indian parlance means that a distribution transformer has been provided to supply power for low tension lines, not that connections have actually been made. (ORG, 1977, p. 57).

Table 8. Extent of Rural Electrification by Size of Population Centers, Andhra Pradesh, India, 1975

Size of Population Center (1971 Census)	Total Number of Villages	Percent of total Electrified
0-499	9733	7.9
500-999	5438	31.6
1000-1999	6421	55.1
2000-4999	4832	76.2
5000-9999	725	89.1
More than 10000	89	100.0

Source: SIETI, Impact of Electrification on Rural Industrial Development: A Study in Kurnool District, Andhra Pradesh (Yousufguda, Hyderabad, SIETI, 1976, p. 107).

off-peak load in a project designed primarily for productive uses.[6] It becomes less justifiable, however (a) if productive uses for electricity are ignored, and (b) if household use is subsidized, as is common in most developing countries, ostensibly to make electricity accessible to the poor, but in practice aiding higher income households.

Use by the Poor. Evidence is strong that electricity is not widely available to the poor, or at least, is much less available to lower income groups than to higher income ones. In Nicaragua, an informal survey of households showed the median income of users at about $100, of nonusers at $57 (DAI, 1977, p. B-27); in Costa Rica and Colombia, users were found to be better educated and have higher incomes than nonusers; and in El Salvador, electrified households had an average family income of 4869 colones ($2,958), versus 1102 colones ($441) for nonelectrified households (World Bank, 1975, p. 73). Table 9 shows generally a very strong correlation between family income and levels of electricity use, with use increasing from 90 kWh annually for the lowest income groups to over 1000 kWh for the highest.

Still, it is strongly felt and observed by many rural electrification practitioners that the rural poor do value electricity and are willing to spend as much as 20 percent of their income on it. The El Salvador study showed that families began to consume electricity at very low levels of income (World Bank, 1975a, p. 74). The Misamis Oriental Survey in the Philippines gave similar results (USAID, 1976, pp. 26-27).[7]

Use by the poor in Latin America, where income levels are fairly high, may also be different in Asia. Another exception in usage by the poor should probably be made for areas such as the Philippines, where rural electrification has been heavily promoted by the government and by the

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6. In India, for example, the recent emphasis has been on paying for a project economically through irrigation uses, with household use merely adjunct.

7. The sampling techniques in this survey have come under attack, however; it has also been pointed out that electricity rates in this area are the second lowest in the Philippines due to cheap hydroelectric power (DAI, 1977, pp. A-33-34).

Table 9. Distribution of Rural Incomes and Electricity Consumption, Connected Households, El Salvador (Salvadorian colones)

Average Family Income Range	kWh Per family Per Year
Less than 600	90
600-1200	100
1201-1800	166
1801-2400	403
2401-3000	254
3001-3600	499
3601-4200	627
4201-4800	590
4801-5400	1225
5401-6000	444
6001-9000	1375
More than 9000	1105

Source: World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D. C., World Bank, 1975).

president personally, and where liberal credit for connections has been provided.

Appliance Ownership. Even in cases where lower income groups do have electric connections, what is it used for? Appliance ownership is the single most important determinant of electricity consumption and its growth, and family income correlates strongly with appliance ownership. The first and most important household use of electricity at all income levels is for lighting (NCAER, 1977, p. 39; NEA, 1978, p. 23; Davis, 1973, p. 14). Ironing and fans in some climates appear to be the most popular uses, with radios and TV following. At higher income levels, refrigerators, blenders, washing and sewing machines, record players and even electric stoves are purchased.

Table 10 gives some data on appliance ownership by connected households in rural areas. Several points are of interest here. First, the results for India point to low appliance ownership generally, but surprisingly high appliance ownership in some backward areas. Second, in the Philippines (and probably elsewhere if there were data available), it is clear that more people use appliances--in particular television sets and refrigerators--than own them. (This effect is somewhat stronger incooperative-electrified areas of the Philippines than in noncooperative areas.) Finally, it is of interest that appliance usage in the United States shortly after rural electrification was also of the same order of magnitude as in developing countries today, with lighting probably being the most important single use of electricity.

It should be noted here that one possible advantage of appliance ownership, saving labor, may not be of great importance in developing areas, where alternative employment opportunities are limited (though saving the drudgery of many household tasks may still be a benefit). However, if a broader definition of appliances is used, to include household water pumps and cornmills, other productive uses of electricity in the home become possible. One observer describes how these electrical "appliances," used by low income families in the Mexican PIDER rural

Table 10. Appliance Ownership in Some Rural Areas (% of electricity consumers owning)

	Iron	Radio	TV	Fan	Refrigerator	Electric Stove
Tisma, Colombia	86.9	41.0	12.6	-	12.1	8.7
San Carlos, Costa Rica	96.5	30.4	24.6	-	27.5	18.7
El Salvador	58	23	39	-	30	4
India (some areas)						
OA (ordinary advanced)	4.6	27.7	-	6.9	-	
OB (ordinary backward)	10.2	22.8	-	7.8	-	
SU 1 (special under-developed - hilly)	15.4	11.0	-	3.3	-	
SU 2 (special under-developed - tribal)	3.6	13.6	-	12.7	-	
Philippines						
Cooperatives						
Owners	47	43	32	27	24	6
Users	53	50	59	33	31	7
Non-cooperatives						
Owners	70	50	48	40	34	10
Users	72	52	72	42	38	11
Rural United States, 1930s	-- 84.3 --		-	-	20	-

Sources: J. Michael Davis, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification, An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia. Report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973); U.S. Department of Agriculture, Rural Electrification Administration, Rural Lines: The Story of Cooperative Rural Electrification (Washington, D. C., GPO, 1972); Operations Research Group, Consumer Response to Rural Electrification (Baroda, ORG, October, 1977); Lalit K. Sen and Girish K. Misra, Regional Planning for Rural Electrification. A Case Study in Suryapet Taluk, Nalgonda District, Andhra Pradesh (Hyderabad, National Institute of Community Development, 1974); National Electrification Administration, Nationwide Survey of Socio-Economic Impact of Rural Electrification (Philippines, NEA, June 1978); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D. C., 1975).

development project, have saved several hours of work a day in lifting water and grinding corn for household use, permitting the irrigation and cultivation of home gardens and resulting in greatly improved nutrition among families (Auguste Schumacher, personal communication, June 1979).

Agriculture. Though household benefits of electrification may be of some importance, the more significant potential for economic development through rural electrification lies in its use in productive enterprises, in agriculture and industry. Electricity for these uses can be generated privately through autogeneration or publicly from the grid. This section examines the use and benefits of electrification in the agricultural sector.

Electricity can be used on the farm in three main ways. First, it may be used on a day to day basis by large commercial agricultural enterprises, in heating and lighting for hatcheries and poultry farms, and milking machines and cooling for dairy farms. There is evidence that the benefits of electricity for those uses can be quite substantial (see table 16 below) but they require a reliable and continuous supply source. Second, electricity may be used to power seasonally needed agro-processing equipment that can remove labor bottlenecks at harvest time, such as threshers, hullers, millers, and crushers. These uses will be dealt with in the following section.[8] Third, electricity can be used for irrigation: this section concentrates on this most important use.

The most interesting country in this respect is India, where the emphasis in electrification has shifted from households to irrigation tubewells, in the interest of increasing agricultural productivity. The analysis here will lean heavily on the Indian situation for this reason. The interest of the Indians in irrigation is understandable: 54 percent of the total variance in agricultural production for India as a whole is

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8. In India, Electricity Board rules do not permit these "non-agricultural" uses on an agricultural irrigation connection because tariffs are lower for irrigation than for agro-processing. This is also a reason for the extreme underutilization of pumpset motors, which could potentially be used for these purposes as well.

explained by irrigation, and that variance increases to 70 percent if Gujarat and Rajasthan are excluded (NCAER, 1978, p. 109). Agricultural consumption as a percentage of total electricity consumption in states of India (including metropolitan areas) has been as high as 29 percent (Tamil Nadu) to 39 percent (Haryana), although the average for all India is 12.6 percent (Sen Gupta, 1977, table 4). Referring back to table 4, the share of irrigation in total consumption in the Indian projects is much greater than that of any other country; however, looking again at table 2, it is clear that the electrification of tubewells has not taken place on a scale as wide as was originally hoped for.

The impact of irrigation on a suitable area can be dramatic, with the value of output often increasing severalfold in a short period. Some results for India are given in table 11. An increase in value of agricultural output can come from (a) an increase in irrigated area, (b) greater cropping intensity--being able to grow another crop or even two during the dry season or (c) a change to higher value crops which require irrigation. This last appears important in the Indian areas surveyed. For example, in Pattikonda Taluk, a 20 percent increase in irrigated area resulted in a Rs. 271,000 increase in the value of agricultural output in that Taluk, primarily due to the switch from lower value grains such as korra, jowra, and bajra, to paddy, groundnut, vegetables, and other higher value cash crops. The change in output and cropping patterns in newly irrigated areas due to electrification is even more striking.

Lift irrigation can be accomplished quite effectively using diesel motors; most benefits from irrigation cannot therefore be attributed to electrification per se. Since both diesel and electric power can lift water, which is what produces most of the benefits here, a comparison of relative costs, examined in the section on costs below, is of interest. Diesel and electric pumps can also be compared in terms of their effects on output; table 12 illustrates one such comparison with inconclusive results. The returns from any sort of tubewell irrigation are apparently quite good in these schemes. In two of the three, use of both diesel and electric pumps had the best returns per acre. In this case, the availability of

Table 11. Changes in Agricultural Output and Value with Electrification of Tubewells, Kurnool District, Andhra Pradesh, India
(% change and Rs. thousands)

	Electrified "Old Wells"						New Wells			
	Pattikonda Taluk			Dhone Taluk			Pattikonda Taluk		Dhone Taluke	
	% change irrigated area	% change crop output	change in value of output	% change irrigated area	% change crop output	change in value of output	% change crop output[a]	change in value of output	% change crop output[a]	change in value of output
Paddy	63	173	81	60	150	5	new	23	new	278
Korra	(-)100	(-)94	(-)1	(-)100	(-)100	(-)2	--	--	(-)95	(-)36
Jowar	(-)100	(-)100	(-)18	--	--	--	(-)100	(-)5	(-)97	(-)18
Hybrid Joward	--	--	--	--	--	--	--	--	new	11
Bajra	(-)100	(-)100	(-)3	--	--	--	(-)100	(-)1	--	--
Wheat	new	new	6	--	--	--	new	.75	--	--
Groundnut	43	76	88	288	288	22	201	12	(-)55	(-)71
Chillies	78	348	88	new	new	36	new	19	new	155
Vegetables	42	71	15	new	new	7	new	2	new	22
Tomatoes	39	63	7	new	new	9	new	4	new	8
Onions	54	116	8	--	--	--	new	2	new	12
Cotton	--	--	--	--	--	--	--	--	new	3
Subtotal: Increases in crop value			293			79		62.75		489
Subtotal: Decreases in crop value			-22			-2		-6		125
Net Total	20	--	271	248	--	77		56.75		364

Source: Small Industry Extension Training Institute (SIETI), Impact of Electrification on Rural Industrial Development: A study in Kurnool District, Andhra Pradesh (Yousufguda, Hyderabad, SIETI, 1978).

[a]This is the amount of the change in agricultural production that can be attributed soley to electrification, obtained by applying a factor for each crop.

$\frac{A_1 - a_1}{a_1}$ where A_1 = new area irrigated and a_1 = old area irrigated

for old wells, to the increase in agricultural production in new well areas.

Table 12. Returns Per Acre, Using Electric, Diesel, and Both Electric and Diesel as Motive Power for Tubewells, Rural Gujarat, India (Rs.)

	Una Scheme[a]			Bayad-Modasa Scheme[a]			Kodinar Scheme		
	Electric	Diesel	Both	Electric	Diesel	Both	Electric	Diesel	Both
Gross value of output/acre	1,118	801	1,103	889	830	894	1,187	1,305	1,532
Costs/acre	461	361	300	432	303	242	654	794	962
Net returns/acre	657	440	713	457	527	652	533	511	570
Benefit-cost ratio	2.43	2.22	3.68	2.05	2.73	3.69	1.81	1.64	1.59

Source: Shreekaut Sambrani, Gunvant M. Desai, V. K. Gupta and P. M. Shiugi, Electrification in Rural Gujarat: Vol. I Kodinar Rural Electricity Cooperative Ltd: Vol. II Una Scheme; Vol. III Bayad-Modasa (Amhedabad, Center for Management in Agriculture, October 1974) pp. 66, 86, 116.

[a]Rabi (irrigated season only).

diesel as a backup to a variable electric supply may have been important, as well as possible economies of scale--users of both diesel and electric pumps also had the largest land holdings, with diesel-irrigated holdings second in size, and electric last.

There is also some evidence that the small farmer may benefit proportionately more than the large farmer from irrigation, primarily due to more intensive cultivation by small farmers. Note that in table 13, the increase in income per hectare for smaller farmers was in nearly every case greater than that for larger farmers.

Nonetheless, a close examination of the hydrology of a region will be necessary before advocating tubewell (water lifting) irrigation at all. Gravity or rain fed irrigation is sufficient in many areas in countries such as Indonesia and the potential for tubewell irrigation may be limited (McCawley, 1979, p. 42). Indeed, in some electrified areas of India as well, groundwater availability or quality is insufficient to run pumpsets for more than a few hours a day if at all (Sen Gupta, 1977, p. 62).

Industry. Industrial uses of electricity are many and varied. It is difficult to imagine any modern large-scale industry without electricity; some small-scale industrial uses are listed in table 14. Industrial benefits from electricity use are of two types: cost savings and increased output or profit, including the use of new processes only possible with electricity. Cost differences are discussed in the section below on costs and pricing; here the general results of electrification for new industries and industrial expansion in an area will be briefly examined. There are several ways of looking at the impact of electricity on industrial output in an area, none of them entirely satisfactory. The most common is illustrated in table 15--to cite the number of industries which have appeared since grid electrification. Another is to estimate the change in profits after electrification (this could also be done for autogeneration), also used in table 15 (although the data do not give any idea of how large this change is in comparison with past profits). Most new rural industries in these Indian cases appear to have been of the same type as previously--small flour mills, oil ghani (presses), and ground nut crushers--without introducing any new processes.

Table 13. Additional Income Realized by Pumpset/Tubewell Users After Electrification, by Size of Holding, Madhya Pradesh and Uttar Pradesh, India (Rs.)

Size of cultivated holding (hectares)	Average increase in income per hectare (Rs.)			
	Pench	Depalpur	Modinagar	Chandauli
Less than 2.0	1,136	1,176	1,563	1,250
2.1-5.0	626	627	891	449
5.1-10.0	349	277	1,127	293
More than 10.0	178	114	1,429	122
All classes	419	178	1,107	292

Source: Council of Applied Economic Research, Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977).

Table 14. Uses for Electricity in Small Industries, India

Blacksmithy	Coal oven, power blower, metal hacksaw, bench drill grinder, sheet cutting machine
Brass smithy	Polishing machine, gas welding unit, power blower
Carpentry	Wood turning lathe, bench
drilling equipment, wood	
	cutting circular, power driven hand tools
Leather footwear	Power grinder, swing machines
Oil Ghani	Power ghani (crusher), crushing miller, seaver
Pottery	Pottery wheel
Weaving	Semi-automatic loom

Source: Small Industry Extension Training Institute (SIETI) Prospects for Modernising Rural Artisan Trades and Decentralized Small Industries (Yousufguda, Hyderabad, 50045,

Table 15. Number of Industries Before and After Electrification, Indian Schemes by Size of Village

Size of village	Pench		Depalpur		Modinagar		Pattikonda		Dhone	
	BE	AE[a]	BE	AE[a]	BE	AE	BE	AE[b]	BE	AE[b]
Less than 750	1	7	3	8	-	-	-	-	-	-
750-1,500	9	15	5	8	3	6	-	-	-	-
1,501-3,000	6	15	-	-	7	11	-	-	-	-
More than 3,000	-	-	-	-	5	14	-	-	-	-
Total	16	37	8	16	15	31	5	32	4	41
Average increase in net income per user (Rs.)	660		573		3,139					

Notes: BE = Before Electrification; AE = After Electrification.

Sources: Small Industry Extension Training Institute, Impact of Electrification on Rural Industrial Development: A Study in Kurnool District, Andhra Pradesh (Yousufguda, Hyderabad, SIETI, 1976) and National Council of Applied Economic Research, Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977).

[a]One year after electrification.

[b]Up to twenty years after electrification.

Anecdotal evidence is used, too: for example, one report cites 515 small businesses serviced by a rural electric cooperative in the Philippines, including new auto repair shops, box factories, small sawmills, hollow block factories, wood and furnitures, a movie theater, and five new medium and large-scale industries (Herrin, 1979, p. 71). Another report from Latin America cited the increase in business in commercial establishments due to customers coming in to watch television (Davis, 1973, p. 181). While subjective, this information is nonetheless useful: autogeneration or grid electrification probably has led to increased industrial and commercial value produced in many areas. But to attribute all these new industries and changes in output to electrification is undoubtedly a mistake, especially since the causal link between the two has not been satisfactorily described.

A third approach has tried to estimate the difference in profits for case studies of businesses using alternative forms of energy. This approach yields the result that in many cases the net benefits available to industry from using central grid electricity may be quite high: table 16 compares the profits of a number of businesses using their actual source of energy and a hypothetical substitute. Profits in this sample are generally less using alternative energy sources than using electricity--net benefits from electricity are from 0.6 to 100 percent of profits. It is difficult to generalize using this case study method, since as table 16 illustrates, even in an electrified area, electricity may not be the cheapest form of supply.

Indirect Benefits

Electrification in rural areas may have significant indirect effects on economic development, through (1) social and public uses, (2) employment, (3) environmental improvements, (4) foreign exchange savings, (5) impacts on migration and fertility, (6) political stability, and (7) encouraging innovation and modernity. In some cases, these benefits may be of some considerable importance. However, many of these developmental goals could also, perhaps more effectively, be achieved through other means.

Table 16. Case Studies of Comparative Benefits of Centrally-Generated Electricity and Alternatives for Industry, El Salvador
(Salvadorian colones)

	ACTUAL			WITH SUBSTITUTE			
	Type of Energy	Annual Production	Profits	Type of Energy	Profits	Net Benefits of Electricity	Percent of Actual Profits
Coffee Processing							
C1	Steam	0.5m lbs	18661	Electric	17781	-1080	-5.7
C2	Diesel	1.2m lbs	41830	Electric	42351	521	1.3
C3	Electric	2.2m lbs	49356	Autogen.	46020	3336	6.8
Sugar Processing (large)							
S1	Autogen.	3593 tons	0.20m	Electric	0.22m	20939	10.5
S2	Autogen.	46818 tons	2.99m	Electric	2.86m	-124114	-4.2
S3	Autogen.	2909 tons	1.16m	Electric	1.10m	-66468	-5.7
Sugar Processing (small)							
SS1	Oxen	8 tons	177	Electric	158	-19	-1.2
SS2	Electric	97 tons	1569	Diesel	1387	182	1.3
Rice Processing							
R1	Electric	932 tons	113509	Diesel	112879	630	.6
R2	Diesel	191 tons	-3598	Electric	-3943	345	9.6
R3	Electric	1846 tons	261073	Diesel	260289	784	.3
R4	Electric	5455 tons	813920	Diesel	809551	4369	.5
Corn Mills							
M1	Diesel	.18m lbs	351	Electric	475	124	35.3
M2	Electric	.47m lbs	2874	Diesel	2569	305	10.6
M3	Electric	11m lbs	127	Diesel	-17	127	100
Poultry Farms							
PF1	Electric	1.31m eggs	24945	Autogen.	24790	155	.6
PF2	Electric	4.02m eggs	132347	Autogen.	131353	994	.8
Shop Refrigeration							
RF1	Electric	n.a.	119	Kerosine	-431	119	100
RF2	Electric	n.a.	120	Kerosine	-380	120	100
Portable Water Pumping							
W1	Gasoline	.12m gal	n.a.	Electric	n.a.	-41	-
W2	Electric	20.0 m gal	n.a.	Diesel	n.a.	1985	-
W3	Oxen	.09m gal	n.a.	Electric	n.a.	597	-
W4	Manual	.03m gal	n.a.	Electric	n.a.	6	-
Milk Cooling							
MC2	Electric	0.71m bottles	33828	Autogen.	32238	1590	4.7
MC3	Electric	0.44m bottles	20710	Autogen.	19750	958	4.6
MC4	Electric	0.73m bottles	43855	Diesel	43412	443	1.0

Source: World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D.C., World Bank, 1975, p. 100).

Social and Public Uses. Electricity can be used for lighting and vocational teaching in schools, sterilization and refrigeration in health clinics, public water systems, and street lighting. Such uses are likely to benefit the poor disproportionately, especially if these are offered free or nearly free of charge. Some have argued that these public benefits are indeed likely to be more important for the poor than are household benefits, which tend to reach higher-income groups to a large extent, therefore possibly justifying the subsidization of social uses of electricity (Tendler, 1978).

The major causation in public health benefits would appear to be the investment in a school or health clinic, rather than the marginal advantage of electrification. Certainly electrification does not often induce health clinics or schools to be built, unless it is part of a larger developmental package. Public water systems may be extremely important in improving health, but may be powered by diesel engines or use artesian flow.

Street lights appear to have benefits in making people feel more secure and in some cases extending street businesses into the night. Street lights, however, are less likely to be installed in poor areas of towns and villages (Selowsky, 1976), and many Indian villages reportedly have only one street light (the State Electricity Board will install a street light if there are ten domestic connections in a village).

Another semi-public use of electricity that may have considerable benefits is the renting of space by individual families in commercial refrigerators in bars and stores, which by preventing wasteage of food and prolonging supplies of protein sources, such as chicken, can improve nutrition.

These public and social uses of electricity seem of some interest for the benefits of electrification for the poor, and merit further investigation.

Employment. Employment benefits from productive uses of electricity in agriculture and industry could be significant; these benefits are related to (1) the expansions in output already discussed and (2) the existence of a market for the output. The employment benefits of energization are probably greatest for irrigation uses, since more labor-intensive crops are often grown with irrigation and the agricultural season is lengthened. But these benefits are more due to water--which can be lifted using various energy sources--than to electricity. In small industry, marketing may be a significant problem with increasing output, and employment could even decrease with electrification (or other measures to increase productivity). If output and incomes are rising generally in an area, however, markets for small industrial output will also be increasing, and employment effects would be positive on net.

Environmental Improvements. The major energy related environmental problem in developing countries is deforestation and erosion caused by fuelwood gathering for cooking--the largest use of energy for the poor--and heating. Another problem may be the use of dung as fuel instead of returning it to the soil as fertilizer. Electricity is not often a substitute for wood or dung in these uses, though there may be some substitution for wood or charcoal in ironing (NCAER, 1978, p. 105; NEA, 1978, p. 25; World Bank, 1975a, p. 69). However, there has been growing substitution in cooking in areas like Latin America where electrification has been widespread. The major alternative fuel to electricity in practice is often kerosine; but air pollution problems of kerosine in the countryside are minor, although in the household smoke from kerosine and wood burning could be a problem. Diesel engines are notorious, too, for their noise, fumes, and smell. But these environmental minuses would have to be compared with the pollution produced by the fossil fuel energy source used for centrally-generated electricity, taking into account differing efficiencies as well.

Foreign Exchange Savings. The substitution of kerosine and diesel oil by electricity for lighting and motive power could be a net benefit in foreign exchange savings--if the central supply is not based on oil imports as well. In India, for example, central grid electricity is generated using mainly local coal and hydro, while diesel and kerosine are imported. Differences in the efficiency of burning fossil fuels in autogenerators or central station facilities would also have to be considered here. Foreign exchange savings also will not have an infinite value, so these benefits should be measured in terms of a "shadow exchange rate" expressing the true value of a foreign exchange to the economy.[9]

Impacts on Migration and Fertility. Electricity is often thought to have an impact on reducing rural migration to cities through its effects on levels of living, employment, and incomes. The World Bank has found no evidence of this result (World Bank, 1975b, p. 7), and in any event, such an effect would be difficult to monitor. The fact is, there appears to be no evidence on this issue in one direction or another; but if a link could be drawn between electrification and development in rural areas, reduced migration to cities would be a plausible side effect.

Impacts on fertility are similar. The most direct effects on fertility will likely be through higher incomes and family planning programs, to the extent that electrification contributes to these. One study found that birth rates in electrified areas of Misamis Oriental Province in the Philippines have dropped fairly steadily since 1971, and faster than birth rates in areas electrified later or not at all (see table 17). But it is not clear from that data (a) whether birth rates were already dropping in the electrified area before electrification or (b) whether income or other developmental differentials in the electrified and unelectrified areas might better explain the results. In addition, a national population program was launched in 1970 (electrification began in late 1971), and economic development in the area appeared to be advancing generally. Again such an effect on birth rates is plausible, if the linkage is from electrification to development to birth rates. Another study in the Philippines found that 22 percent of electrified families used family planning, versus 19 percent of nonelelectrified, with 17 percent and 23 percent pregnancy rates respectively (NEA, 1978, pp. 38,39). But it was also clear from the study that electrified households had higher incomes and socioeconomic status than unelectrified ones.

Political Stability. The only evidence on this point is also from the Philippines, where a major commitment was made by the government to electrification (and other rural programs) as a means of winning support

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9. For a full discussion of the calculation of shadow foreign exchange rate, see Squire, 1975.

Table 17. Crude Birth Rates, Misamis Oriental Province, 1971-75

	1971B	1972A	1972B	1973A	1973B	1974A	1974B	1975A
Rural west (early electrification)	45.8	39.6	48.0	38.0	39.1	31.6	31.1	29.9
Rural west (later electrification)	--	--	--	--	51.1	32.1	39.3	35.6
Rural east (no electrification)	--	--	--	--	40.9	35.7	40.3	35.5

Source: Alejandro N. Herrin, "Rural Electrification and Fertility Change in the Southern Philippines," Population and Development Review vol. 5, no. 1 (March 1979), p. 67.

away from the Communists in the countryside (Tendler, 1978, p. 5). According to a survey in the Philippines, this strategy worked quite well. A later survey of the "perception of change in the peace and order situation with the coming of electricity" showed that 84 percent of electrified households and 78 percent of nonelectrified households believed the situation was better, with 14 to 19 percent believing the situation was the same (NEA, 1978, p. 27). The effects of electrification in itself may not have been as important, however, as was its evidence of a strong government commitment to the improvement of the rural areas.

Innovation and Modernity. "Electricity is a potent instrument for inducing modernism...it strengthens the forces of change in stagnant attitudes and responses to opportunity of the rural folk." (SIETI, 1976, p. 7). Implicit here is the idea that the true benefits of electrification in rural areas are somehow greater than the sum of its parts, even using the broad framework chosen here.

Certainly, electrification can potentially be important as a "change agent." One study in the 1960s by the National Institute of Community Development of India concluded that apart from the influence of local leaders, the major village resource that seemed to make a substantial difference in the level of adoption of agricultural innovations in Indian villages was the availability of electric power (Fliegel and coauthors, 1971, p. 103). But a change in the availability of any key productive input--such as credit, land, or technology--could have a similar effect under the right circumstances. Clearly, if all inputs are lacking, either they all must be provided for development to take place, or one input must be the stimulus for entrepreneurs to secure the others. A key question is whether electricity has an especially important role to play in rural areas.

Comparative Costs, Pricing, and Subsidies

While electrification has considerable direct and indirect benefits for households, agriculture, and industry in rural areas, these benefits come at some cost. Since resources invested in rural electrification will have other pressing uses in developing countries, comparing benefits minus costs, or net benefits is of great interest in looking at the impact of electrification on economic development in rural areas. In many cases, the same tasks can be accomplished using alternative sources of energy; or if electricity is desirable, by using autogeneration instead of attaching to the central grid. Under costs, this section will focus on some of the major alternatives in practice to central-station electricity in rural areas, for performing similar tasks. These alternatives are autogeneration of electricity for all uses, kerosine for household lighting, and diesel engines for water lifting in agriculture and motive power in industry. The potential from traditional and renewable energy sources as substitutes for electricity are not considered here. Pricing and the operation of subsidies are discussed in the last part of this section.

Autogeneration Versus the Central Grid

Marginal costs of electricity in rural areas are higher than in urban areas due to the dispersed and low nature of demand. Costs for autogeneration of electricity versus centrally-generated supplies depend upon at least four elements:

(1) The cost of generation. In Pakistan, for example, central station electricity is generated using cheap hydro and natural gas with few alternative uses. Autogeneration using mini-hydro may also be very cheap. If excess capacity exists in the central facility, the cost of generation for supplying more kilowatt-hours to rural areas may be very low--only the fuel costs. Rural loads may also be off-peak for the system as a whole. In the United States in the 1920s, for example, one incentive for electric utilities to expand service to rural areas was that urban summer loads--which were only one-fourth of winter ones--could then be augmented by seasonal farm irrigation and machinery demand. The extreme economies of scale that hold in electricity generation mean that at the generation stage, grid power is likely to be much cheaper than autogeneration.

(2) Distance from the grid and density. The more remote the area to be electrified is from the main grid, and the more dispersed demand centers are (for example, isolated farms kilometers apart), the higher the costs of transmission and distribution from the central generating plant.

(3) Load factors. The load factor is the ratio of average to peak consumption for the system. If use and load factors are high, then costs for the more capital-intensive central generating facility will be lower, since they can be spread out over more units of demand. On the other hand, a high load factor means high fuel and operating costs for autogeneration, costs that cannot compete with the operating economies of scale of the central grid. Often residential and agricultural users will have a low load factor since use is for only a few hours a day, usually at the same time (evening for lighting and morning for irrigation), while industrial demand is more spread out through the day and night. The rate structure is often used to improve the load factor for centrally generated electricity by offering concessional rates to these uses with higher load factors.

(4) Other influences. Besides having a high load factor, industrial users are often large consumers but have low costs of connection and servicing for the utility. The terrain through which transmission and distribution lines must be built and the existence of roads and other construction-related infrastructure can also influence the relative costs of autogeneration and the grid.

The interrelationship of these costs for one particular case is shown in table 18. Capital costs are higher for the grid supply, but fuel, operation, and maintenance are higher for autogeneration. Even at a 10 percent case, the grid is more competitive than autogeneration at 4 kilometers, but at 29 kilometers autogeneration is by far cheaper. At a 50 percent load factor, however, the grid is cheaper than autogeneration even at 29 kilometers from the main grid.

Autogeneration is often only a preliminary step to grid electrification. Electrification of rural areas typically proceeds in four phases, aptly described by the World Bank (World Bank, 1975b, p. 4). First, a few isolated (but fairly large and productive and thus able to afford the capital investment and high cost of autogeneration) industries or farms may generate their own electricity for dairy and poultry farms, mining, or possibly refrigeration and lighting in shops. At this point, small farms and industries are using small diesel engines, animals, or human labor for motive power.

Table 18. Typical Comparative Costs of Autogeneration and Central Grid, El Salvador (U.S. $ thousands)

Cost Components	Autogeneration			Grid		
	Load Factor					
	10%	25%	50%	10%	25%	50%
Annual capital costs	4,500	4,500	4,500	5,600	5,600	5,600
Fuel, operation, and maintenance	2,600	6,600	13,200	200	500	1,000
Billing and administration	2,000	2,000	2,000	2,000	2,000	2,000
Total[a]	9,100	13,100	19,700	7,800	8,100	8,600
Average kWh cost (¢)						
4 km	21	12	9	18	7	4
29 km	--	--	--	40	17	8

Source: World Bank, Rural Electrification: A World Bank Paper (Washington, D. C., World Bank, 1975) pp. 20-21.

[a] Costs are for grid at 29 km only.

Later, small networks may form around autogeneration centers for other households, businesses, and farms. In the third phase, these "microgrids" and other major demand centers are connected and hooked up to the main grid system. Finally, centers of low demand can be connected at very low marginal cost.

In a sense, therefore, the question would be not autogeneration versus the grid for areas where substantial population exists and incomes are expected to increase, but one of timing as to when demand will justify the distances involved. But for many isolated agricultural, mining, and other uses, connection may be very long in coming.[10] Autogeneration may have to suffice for many rural uses for a long time--does this mean long term, higher energy costs for these consumers? Not necessarily--the costs used above appear to refer to conventional diesel autogeneration but small generation units can be powered by a variety of sources including biogas, wind, mini-hydro, and photovoltaic cells, where appropriate. Referring back to table 16, it is clear that even in an electrified area, central electricity may not be the cheapest form of supply. The coffee mill (Cl) with negative benefits from (hypothetical) electrification was too far from the transmission line to make a distribution line worthwhile; the sugar mills (S2, S3) were generating their own electricity partly from sugarcane wastes, and in another case (SS1), using oxen for a very low level of production; and the gasoline-powered water pump engine (W1) had been purchased second hand.[11] The possibility that locally available renewable sources of fuel or special circumstance might make autogeneration more economical in some cases needs to be further investigated.

In addition, there are a number of reasons why the net advantages of the central grid may be overestimated in rural areas. Subsidies will be

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10. Even in the United States, for example, the costs of running electric lines to some rural areas of the West to operate water pumps for cattle have caused farmers to turn to windmills for autogeneration (Wall Street Journal, 14 June 1979, p. 1).

11. It is also illuminating that investigators found that in every case, businesses had on their own chose the profit-maximizing form of supply, except where the producer had already bought other energy equipment before electrification.

discussed at length later. As important may be the notorious unreliability of rural power systems--which discourages productive applications in particular. While maintenance problems and outages of autogenerating capacity are well known and expected, power shedding due to a shortage of generating capacity in the central grid is not infrequent either: more than half of all consumers in "advanced" rural areas in an Indian survey reported daily power cuts, and more than eighty percent weekly cuts. In the Philippines, 77 to 96 percent of households in electrified areas reported from one to ten power interruptions in the previous month (ORG, 1977; USAID, 1976). Voltage fluctuations can damage equipment or affect its use as well. For both these reasons, many productive users of electricity maintain back-up generators at high cost. It has been argued that the central grid transmits these outages and voltage variations to all parts of the system, and that if losses from downtime were taken into account, they might be less in total for autogeneration than for the grid (Tendler, 1978, p. 45). But it is difficult to see why this should necessarily be so: indeed, maintaining autogeneration capacities demands scarce technical and managerial skills as well. The operation and maintenance of small (40-1,000 kw) diesel generators has been reported as comparatively complicated and requiring unavailable technical staff, with equipment only lasting three to four years, according to developing country representatives to an ESCAP meeting on rural electrification (McCawley, 1979, pp. 44-45). One advantage to autogeneration not included in cost comparisons is certainly that it spreads out capital costs of electrification by making small investments in capacity as demand develops, thus minimizing the uncertainties inherent in projecting rural loads (Tendler, 1978, pp. 51-52). It is nonetheless not clear on net whether these uncounted costs of centrally-generated electricity are as important in relative costs as the generation, distance, and load factor aspects discussed earlier.

Other Fuels in Key Economic Development Uses

Kerosine in Lighting. It is difficult to compare costs of electricity with those of other sources for households, because in many cases the energy service provided by electricity is so much higher quality (lighting), convenient (ironing), or unavailable with other energy sources (TV) that the service is essentially a new and different one.

Lighting is one energy service in which, at least in rural areas, electricty and kerosine may be substitutes to an extent, although electric lighting is higher quality and more convenient. As table 19 shows, kerosine is often used as a backup to electricity even by connected households. Total costs for energy are often higher for electrified households than for unelectrified ones, but since these new and different services are being used, such a difference is not surprising. The introduction of electricity should not for this reason be expected to reduce total household expenditures on energy in most cases.

The cost comparisons--essentially for lighting--in table 19 are not completely accurate, however, since the electricity charges include other loads such as ironing and fans. A further complication is that electrified households probably have higher incomes overall than nonelectrified ones, so their total energy expenditures would likely be higher in any event. More detailed studies of costs for comparable services and at the same income level are necessary in order to make any more meaningful conclusions here.

Water Lifting: Diesel Versus Electric. The most important use for electricity in increasing productivity in agriculture appears to be though powering irrigation pumpsets. The major energy alternative to the central grid for motive power for lifting water in practice has been diesel engines, though windmills, oxen, biogas plants, and autogeneration of electricity have also been proposed as alternatives.[12] Diesel engines are also often used for motive power in industry; many of the costs and arguments presented below apply to industrial use as well.

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12. Ramaswamy (1978) believes the existing stock of bullocks in India are less expensive to use than electricity for shallow water lifting; Bhatia's (1979) calculations show biogas as more economical in one rural area of India than diesel, electric, or photovoltaic power; autogeneration has already been discussed.

Table 19. Household Expenditures on Electricity and Substitutes for Lighting, Selected Areas (costs per month)

	Candles		Kerosine		Electricity		Total Average Cost
	% Using	Cost	% Using	Cost	% Using	Cost	
Costa Rica[a]							
Electrified	16	.05	47	.26	100	2.14	2.48
Non-electrified	75	.52	74	.45			1.05
Colombia[a]							
Electrified	41	.09	81	.92	100	.36	1.36
Non-electrified	98	.51	83	.74			1.25
India[a] (Pench, M.P.)							
Electrified				.20		.79	1.00
Non-electrified				.86			.86
India[a] (Depalpur, M.P.)							
Electrified				.22		.54	.76
Non-electrified				.56			.56
India[a] (Modinagar, U.P.)							
Electrified				.22		1.34	1.56
Non-electrified				.75			.75

Sources: J. Michael Davis, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification, An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia. Report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973) and Council of Applied Economic Research, Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977).

Costs of electric versus diesel pumpsets are much disputed. As diesel prices continue to rise, their relative competitiveness will fall. Table 20 gives some ranges of costs of tubewells in India in the mid to late 1970s. Capital costs for electric motors are generally higher than for diesel, while maintenance and operating costs tend to be higher for diesel. Downtime for repairs to diesel engines has been reported as high as 30 percent greater than for electric, but on the other hand, outages due to load shedding may be as important for electric pumps. Convenience and easier maintenance are often cited among the advantages of electric motors (ORG, 1977, p. 148; NCAER, 1978, p. 159) while movability of diesel engines is an advantage where landholdings are scattered. Administrative roadblocks and delays in installing diesel engines are also reportedly much lower (Child, 1975, p. 259).

Using a 10 percent rate for annualizing capital costs, electric motors have a total cost advantage over diesel engines in table 20 in all but Bhatia's social cost calculations for the Bihar area of India and in the Chandauli scheme. Note, however, that the choice of a 15 percent rate would make diesel engines cheaper than electric motors in four of the seven cases--at their current oil prices. Furthermore, since both diesel fuel and electricity are subsidized in India and many other developing countries, the comparisons in table 20--with the exception of Bhatia's--reflect only the private market prices, not the social costs of supply. Bhatia's study, which gives shadow prices to labor and capital inputs and, more importantly, costs electricity and diesel fuel at their social cost, taking subsidies, for example, into account, shows a cost advantage for diesel in Bihar, especially if the 15 percent is used for annualizing capital costs.[13] This confirms a 1969 study which

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13. Bhatia uses Rs. 1.6/liter as the social cost and Rs. 1.41/liter as the market price of light diesel oil; and Rs. .12/kWh and Rs. .40/kWh as the market price and social cost of electricity, respectively. Bhatia, in fact, believes that the most economical energy source of all for water lifting is biogas, if shadow prices for inputs and the social cost of supply of diesel and electricty are used.

Table 20. Comparative Costs of Diesel Engines and Electric Motors for Irrigation, India
(Rs.)

	CAPITAL COSTS		OPERATING COSTS						ANNUALIZED CAPITAL COSTS AT 10%		TOTAL ANNUAL COSTS	
			Electric			Diesel						
	Electric	Diesel	Power	O & M	Total	Fuel	O & M	Total	Electric	Diesel	Electric	Diesel
Modinagar	6147	4954	305	231	536	600	193	793	615	495	1151	1288
Chandauli	4454	4330	220	102	321	131	97	228	445	433	766	661
Depalpur	3655	2550	29	21	50	84	87	171	366	255	416	426
Pench	3364	389/	86	53	139	138	57	195	336	390	475	585
Lalit Sen in Ramsay	4560	4720	1004	470[a]	1474	2215	500	2715	456	472	1930	3187
Bhatia												
Market Price	6075	3300	216	1200	1416	630	1536	2166	608	330	2024	2496
Social Cost	7350	3150	720	900	1620	720	1236	1956	735	315	2355	2271

Sources: National Council of Applied Economic Research, Cost Benefit Study of Selected Rural Electrification Schemes in Madhya Pradesh and Uttar Pradesh (New Delhi, NCAER, 1977); Ramsay, W . and J. Dunkerley, "Trip Report on India, January 1-17, 1979," Resources for the Future; and Bhatia, Ramesh, Energy Alternatives for Irrigation Pumping: Some Results for Small Farms in North Bihar (Delhi, Institute of Economic Growth, 1979).

[a]Includes maintenance and depreciation on mains, prorated.

concluded that although the private costs of irrigation with a diesel engine were 50 percent above those for an electric motor, adjusting for appropriate shadow prices, the social costs of diesel were two-thirds those of the electric motors (Child, 1975, p. 259).

Pricing and Subsidies

Pricing. Some representative charges for electricity in rural areas by category of consumer are given in table 21. Prices for power vary enormously in developing countries, from as low as .5¢/kWh for large industry in India, to 16¢/kWh for domestic lighting in Mauritania. Rates appear to be generally lower in Latin America and Asia, and highest in Africa. In general, domestic rates for lighting are in the 3-10¢/kWh range, with domestic power (for appliances) only slightly lower on average. High tension (large) businesses typically pay lower rates than low tension (small to medium) businesses, with rates averaging around 1-9¢/kWh for LT and 107¢/kWh for HT. (Larger users will tend to pay towards the low end of the prices, since most tariff structures are declining block: the first block of, say, 50 kWh, costs 10¢/kWh, the next of 200 kWh costs 8¢/kWh, and so on). Irrigation is in the 2-8¢kWh range, and public street lighting also around 2-8¢/kWh.

Prices for electricity in rural areas should be typically higher than in urban areas but below average costs in the early years of a project, (a) because costs are very high before demand has developed to a reasonable load factor, and (b) in order to promote the use of electricity and an increase in the load factor (World Bank, 1975b, pp. 8-9). Thus at the beginning of a rural project, one would not expect financial viabiity.[14] Often a rural electrification cooperative will be expected to cover operating and maintenance expenditures out of revenues, while capital costs are picked up by the central system or government. As the load factor and

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14. The Rural Electrification Corporation of India expects negative returns on projects in "ordinary advanced" areas up to the sixth year and 3.5 percent returns by the end of the fifteenth; for "ordinary backward" areas, negative 3.5 percent at the end of the fifth year, breakeven at he end of the tenth, and 3.5 percent after twenty years (SenGupta, 1979, p. 2).

Table 21. Selected Variable Charges for Electricity (US ¢ per kWh)

	Domestic Lighting	Domestic Power	Commercial/ Industry (Low Tension)	Large Industry (High Tension)	Irrigation/ Water Pumps	Street Lights
Ethiopia (EELPA)	6-4*	2*	4-2*	4-2*		
Ghana (ECG)	9	2*	2*	2*		
Mali (EM)	12-8	12-8	11-8	10-6		8
Mauritania (SAFELEC)	16		14	11*		14
Iraq (NEA)	3	3	1*	1*		
Syria (DES)	4		5-2	5-2		3
Cambodia	9	9	6	5	6	8
India						
Bombay	2	2-1	2-1	1-.5*		1
Laccadine Islands	8	8	5-4	8	8	8
Philippines (DAI, 1977)						
Camarines Sur I (1974)	5	5	7	5		3
(1976)	9	9	8-3	9	8	4
Albay (1974)	5	5	5			4
(1976)	8	8	8-5			4
Thailand (MEA)	5-3	5-3	9-3	2-1*	3	2
Vietnam (SCES)	3	2	2	2	2	2

Table 21. (cont'd.)

Argentina (SEGBA)	3*	5*	5-4*	2*	2	3
Bolivia (DAI, 1977)	5		3	3	8-3	5
El Salvador						
CEHRL	6-2	6-2	6-2	2*	2	3
CEL (El Sal, 1975)	4-2		5-1	2-1*	2	3
CAESS (El Sal, 1975)	3-1		2-1	2-1*	2	
Mexico (CFE)	3*	3*	4-1*	2-1*	1	1
Nicaragua (DAI, 1977)						
ENALUF	2	2	1	1	3	3
CONODER	9-11		6	9-4*	3	5

Note: Most charges are for rural areas; some of the African and Middle Eastern utilities may not be in rural areas but have been included for comparative purposes. Undated citations are from Electricity Costs and Tariffs: A General Study (New York, United Nations, 1972) and are presumably from the early 1970s. Where two figures are given, the first (usually higher) is for the first block of power; the second for the last block or off-peak (the size of these blocks varies from country to country). An asterisk means some fixed charge related to maximum demand or other parameters is also charged in addition to the variable charge given.

Sources: J. Michael Davis, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification, An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia. Report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973); Development Alternatives, Inc., An Evaluation of the Program Performance of the International Program Division of the National Rural Electric Cooperative Association (NRECA). Report to U.S. Agency for International Development (Washington, D. C., DAI, January 28, 1977); Peter McCawley, "Rural Electrification in Indonesia--Is It Time?" Bulletin of Indonesian Economic Studies, (1979); Shreekaut Sambrani, Gunvant M. Desai, V. K. Gupta and P. M. Shiugi, Electrification in Rural Gujarat: Vol. I Kodinar Rural Electricity Cooperative LTD: Vol. II Una Scheme: Vol. III Bayad-Modasa (Amhedabad, Center for Management in Agriculture, October 1974); United Nations, Electrificy Costs and Tariffs: A General Study (New York, UN, 1972); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D. C., 1975).

density of use increases over time, however, returns should rise. But continued low use, declining block rates to large users (as table 21 shows), and pricing below consumer's willingness-to-pay often combine to frustrate this goal. In some cases, too, where use is low, expansion comes through extending the grid rather than through rising load levels.

Subsidies. Subsidies to rural electrification projects are general, and of three main types:

(1) Cross-subsidies from one category of consumer to another, such as from domestic to industrial uses. In Nicaragua, for example, domestic and commercial use subsidizes irrigation and large industry (DAI, 1977, B-32). The rates in table 16 may be somewhat indicative of cross-subsidies, but not entirely so, since the marginal costs of supplying different consumer varies; large industrial users will often have low connection, servicing, and metering costs per user, as well as high load factors which will reduce system costs; while the per user fixed costs of connection, etc. for residential and irrigation users will be high.

(2) Government subsidies to the rural electrification system often take the form of interest-free loans, while operating and maintenance expenditures are financed through revenues. In this case, other parts of the economy are paying for rural electrification. Often, however, even operating costs may not be covered in the early years: table 22 is the financial statement for an Indian rural electric cooperative in its first three years. Excluding capital costs, the average per kWh subsidy varied from .25 to .43 of a cent; and even as the load rose from 2.86 to 9.1 million kilowatt-hours sold, the percentage of subsidy did not drop consistently--from 17.6 percent of costs to 11.8 percent, then back to 16.6 percent. Another study in Nicaragua found marginal costs of from 29.5 percent (residential) to 223.3 percent (irrigation) of prices for electricity in 1975 (DAI, 1977, B-32).

(d) International loans at concessional rates are also a source of subsidies for developing country rural electrification programs. Rates as low as 2 percent and grace periods of ten years or more are not uncommon by international donor organizations for backward areas. It can be argued that this capital still has an opportunity cost to the economy of the

Table 22. Financial Statement, Kodinar Rural Electric Cooperative, Gujarat, India 1970-1973 (U.S. $ and ¢)

	1970-71	1971-72	1972-73
Million units	2.86	4.59	9.10
Cost of electricity	44634	74024	154024
kWh cost (¢)	1.56	1.61	1.69
Cost of electricity plus operating expenses	62682	95853	188780
Total kWh cost (¢)	2.19	2.09	2.07
Sales revenues	51585	84390	157073
kWh sale price (¢)	1.80	1.84	1.73
Net loss	5000	11463	31707
Average kWh subsidy (¢)	11.0%	15.5%	20.7%

Source: Sambrani, Shreekaut Gunvant M. Desai, V. K. Gupta and P. M. Shingi, Electrification in Rural Gujarat: Vol. I, Kodinar Rural Electricity Cooperative Ltd; Vol. II Una Scheme; Vol. III Bayad-Modasa (Amhedabad, Center for Management in Agriculture, October 1974).

[a]Converted to U.S. dollars from rupees at 8.2 Rs/$U.S.

developing country involved, since it would be loaned in that country in any event for some other purpose. But this is less the case where specific funds and lending rates assigned specifically for rural electrification, as for example in recent USAID programs.

Effects of Electrification on Consumer and Producer Decisions

There is nothing inherently wrong with subsidies to rural electrification if they accomplish the objectives for which they are designed. As has already been shown, household benefits from subsidies to rural electrification rates, especially those other than lighting, are mostly received by the relatively better off in rural areas. Quite high returns are experienced by production-oriented users of electricity, as tables 11 and 16 have shown, respectively, making subsidies unnecessary here as well. The case for electrification (and for the subsidization of electric rates) rests on the assumption that users will make different decisions about consumption, production, and location of enterprises on the basis of the availability and the price of electricity. This section argues that availability and reliability are more important than price in these decisions, particularly for new and productive users, because (1) electricity itself is only a part of the total costs of using electric power for households and business, and (2) energy is only a small portion of total operating costs of most businesses.

Households

The total costs of using electricity in households includes the costs of connection and the cost of appliances, as well as the cost of electrcity. Table 23 compares costs for electricity and its substitutes. For these uses, the costs of electricity itself are from 30 to 60 percent of the total costs of using electricity. Once expenditures on connections and appliances have been made, however, the price of electricity will probably

Table 23. Total Cost Comparisons Between Electricity and its Substitutes, El Salvador (Salvadorian colones)

	Electrical Appliances				Substitute	
	Connec-tion	Appli-ance	Electri-city	Annual Total	Type	Annual Costs
Lights	60	5/year	10	22	Kerosene	7-13
Iron	60	35	7	20	Flat iron	5
Refrigerator	75	1,200	80	260	Kerosene	500
Cooking	75	300	70	120	Wood	75

Sources: J. Michael Davis, John Saunders, Galen C. Moses, James E. Ross, Rural Electrification, An Evaluation of Effects on Economic and Social Changes in Costa Rica and Colombia. Report to U.S. Agency for International Development (Center for Tropical Agriculture, Center for Latin American Studies, University of Florida, Gainesville, Florida, 1973); U.S. Department of Agriculture, Rural Electrification Administration, Rural Lines: The Story of Cooperative Rural Electrification (Washington, D.C., GPO, 1972); Operations Research Group, Consumer Response to Rural Electrification (Baroda, ORG, October, 1977); Lalit K. Sen and Girish K. Misra, Regional Planning for Rural Electrification. A Case Study in Suryapet Taluk, Nalgonda District, Andhra Pradesh (Hyderabad, National Institute of Community Development, 1974); National Electrification Administration, Nationwide Survey of Socio-Economic Impact of Rural Electrification (Philippines, NEA, June 1978); World Bank, Costs and Benefits of Rural Electrification: A Case Study in El Salvador, P. U. Res. 5 (Washington, D.C., 1975).

have more of an effect on consumption.[15] But subsidies to electric rates alone are unlikely to have a substantial effect on consumption, unless subsidies or liberal credit are also provided for connections and appliance purchases.[16]

Irrigation

As in the case of households, total cost of electricity for irrigation include costs of connection, pumpsets, and electricity. Connection costs for pumpsets have been estimated by Bhatia at Rs. 3,000 higher than his estimate of Rs. 2,075 for the electric motor itself (Bhatia, 1979, table 6). Total costs of connection, digging a well, and the electric motor in India appear to range from Rs. 4,000 to Rs. 7,000 ($500-$850), making the cost of electricity itself a fairly minor part of total costs. Subsidizing electricity rates therefore is unlikely to have a substantial impact on the decision to irrigate unless these other costs are also subsidized or credit liberally provided, especially for small farmers. Lack of credit has often been cited as an obstacle to small farmer irrigation: in parts of India, for example, a minimum of 1.5 to 2.5 hectares of land has to be offered as security for loans for pumpsets, where more than 30 percent of farmers own less than .74 hectare (SenGupta, 1977, pp. 41-42). MORESCO, a Philippine utility in a rural area near Manila, has lent money for electricity-using irrigation pumps with some success (USAID, 1976, p. 45).

Furthermore, irrigation is only a part of total operating expenses for a farm, which include purchases of seeds, fertilizers, implements, storage, and marketing. Differences in the price of electricity are probably less crucial than its availability and reliability; cases of farmers maintaining both diesel and electric pumpsets have already been noted.

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15. Although the case is cited of flat rates for electricity being so low that customers leave light bulbs burning all month, in order to save the filament.

16. One section of the U.S. Rural Electrification Cooperative Act provided for loans to homes, farmers, and businesses in newly electrified areas to purchase electricity-using home appliances, farm machinery, and other equipment.

Large Industries

Autogeneration of electricity is a clear option for large industries wishing to locate in an unelectrified area. A legitimate question then is why large industries have not already located in an unelectrified area, using autogeneration? And why should large firms choose to locate there if the area becomes centrally electrified, with possibly lower costs of electricity? One likely reason is electricity costs through autogeneration on a small scale are often higher than the costs of centrally producing electricity, due to lower marginal costs in the central system (with its economies of scale and maybe hydro) and the fact that industrial demand is often off peak load for the system as a whole (Selowsky, 1975).

Kilowatt-hours are only a part of the total cost of using electricity, which includes motors and machines. In addition, electricity costs are only a small portion of total costs of most large industries, as is evident from table 24. Only two industries of those likely to enjoy locational advantages in rural areas--cement and pulp, paper, and paperboard--have electricity costs greater than 10 percent of total costs. Marginal advantages in the cost of electricity in rural areas are likely to have little difference in locational or production decisions for most large industries, therefore; availability and reliability may be more important. For example, in Nicaragua, most agro-industrial users preferred central station electricity for its convenience but also kept generators for supplementary and emergency use: milking cows, cooling milk, incubating eggs and lighting poultry farms requires continuous service. A hatchery even had an automatic switching device to a gas generator (DAI, 1977, B-20).

Small Rural Industries

The record for establishment of new small-scale industries in newly electrified rural areas is a rather poor one. One report from India cites average new employment per year per taluka (sub-district) in industry in Karnataka after electrification as six persons (SenGupta, 1979, p. 10). Production decisions for small rural industries are a different matter than for large. The costs of autogeneration per kilowatt hour are much higher

Table 24. Share of the Expenditure of Electricity on Total Operating Costs, Chilean Manufacturing Census 1967

	ISIC Classification	Share of electricity in total cost (%)
201	Slaughtering, preparation and preserving of meat	0.2
202	Manufacture of dairy products	1.4
203	Canning and preserving of fruits and vegetables	0.6
204	Canning and preserving of fish and other sea foods	2.1
312	Vegetable and animal oils and fats	2.1
205	Manufacture of grain mill products	1.6
206	Manufacture of bakery products	1.2
207	Sugar factories and refineries	3.6
208	Manufacture of cocoa, chocolate and sugar confectionary	1.1
209	Manufacture of miscellaneous food preparations	1.4
211	Distilling, rectifying and blending of spirits	1.0
212	Wine industries	1.0
213	Breweries and manufacturing of malt	2.6
214	Soft drinks and carbonated water industries	1.2
220	Tobacco manufactures	0.3
231	Spinning, weaving and finishing textiles	2.5
232	Knitting mills	1.4
233	Cordage rope and twine industries	3.7
243	Manufacture of wearing apparel except footwear	0.6
241	Manufacture of footwear	0.6
291	Tanneries and leather finishing plants	1.5
293	Manufacture of leather products (except footwear)	0.8
251	Saw mills, planing, and other wood mills	1.7
252	Wooden and cane containers	2.7
259	Manufacture of cork and wood products (except furniture	2.1
260	Manufacture of furniture and fixtures	1.4
271	Manufacture of pulp, paper and paperboard	10.1
272	Manufacture of articles of pulp, paper and paperboard	1.5
331	Manufacture of structural clay products	3.8
334	Manufacture of cement	11.8
	Manufacture of cement products	1.2
	Manufacture of fiber-cement products	1.2
	Manufacture of plaster products	3.2

Source: Marcello Selowsky, The Distribution of Public Services by Income Groups: A Case Study of Colombia, Part I (Electricity, Water, Sewage) (Draft, Washington, D.C., World Bank, August 1976).

for very small scale use. There is some evidence, too, that fuel costs are a higher proportion of total production costs in small industries than in large. Table 25 shows very high percentages for flour mills (25.7), pottery (29.9) and gur making (12.9). While total costs may be underestimated here (it is not clear in the source whether figures given for wages include self-employed labor of the artisan and his family), these shares of energy in total costs are on the whole much higher than those for large industries (total energy costs for large industries would be higher if nonelectric sources were included, but it is hard to imagine them more than doubling). Changes in the price of electricity might therefore have more of an effect on production decisions of small industries than large.

Electrified small rural industries appear to be more heavily capitalized than nonelectrified, as well as producing more output and profits per worker. Table 26 shows a steady progression in both capital-intensity and output per worker as typically small-scale industries move from traditional production technologies to manually-operated machines, and finally to electrically-powered machines, even those of very small horsepower.

The incentives for electrification in order to achieve these higher output and profit levels are weak for small rural industries, however. The difficulties are twofold: first, raising the necessary capital to improve productivity, and second, finding a market for the extra production. If no markets can be found for extra production, then higher productivity simply means less employment, not a desirable result in the labor-surplus economies of most developing countries. If output and incomes are increasing generally with electrification, however, small industry output of consumer goods and agricultural implements should have no difficulty finding markets.

This problem of finding markets for increased production is especially severe for small industries, that have traditionally sought local markets. Such constraints on increasing output have been reported in Indonesia for coconut sugar and bamboo processing (McCawley, 1979, p. 42). One study found that most artisans and small craftspeople in several districts felt there was no scope for using power in their work because there would not be a demand for their goods or services if production were increased (SIETI,

Table 25. Fuel as a Percent of Total Production Costs, Artisan Crafts and Small Industries, India[a]

Industry	Percent
Black smithy	2.3-3.9
Brass smithy	2.2
Metal works	.1
Carpentry	.05-12.0
Flour mills	25.7
Flour and oil	15.8
Khandasari and oil	1.2
Pottery	29.9
Gur (palm) making	12.9
Oil ghani	.3
Palm fibre	3.0

Source: Small Industry Extension Training Institute (SIETI), *Prospects for Modernising Rural Artisan Trades and Decentralized Small Industries* (Yousufguda, Hyderabad, SIETI, 1978).

[a]Total costs may be underestimated, since it is not clear whether "wages" include self-employed labor of artisan and family.

Table 26. Labor-Intensivity and Productivity in Small-Scale Industries With Different Production Technologies, India (Rs.)

	Traditional	Manual Machines	Power Machines
Black smithy			(1.25HP)
labor/capital	.8	.25	.05
output/worker (Rs)	1,000	1,750	5,000
Brass smithy			(.75HP)
labor/capital	1.33	.8	.08
output/worker (Rs)	1,750	4,000	9,000
Carpentry			(4HP)
labor/capital	.4	.2	.05
output/worker (Rs)	1,750	2,500	5,500
Leather Footwear			(.5HP)
labor/capital	6.67	2.0	.18
output/worker (Rs)	1,800	2,438	7,200
Oil Ghani			(5HP)
labor/capital	.28	.13	.04
output/worker (Rs)	6,750	14,750	23,450
Pottery			(1/8HP)
labor/capital	4.0	1.33	.2
output/worker (Rs)	1,000	1,250	1,875
Weaving			(1HP)
labor/capital	.73	.50	.08
output/worker (Rs)	1,350	3,000	10,000

Source: Small Industry Extension Training Institute (SIETI), Prospects for Modernising Rural Artisan Trades and Decentralized Small Industries (Yousufguda, Hyderabad, SIETI, 1978).

1976). This problem is further complicated in India by the common contract system, whereby a trader provides raw materials on credit, then deducts their cost from the sale price he gives the artisan, effectively paying him wages. Cooperatives in some localities have helped artisans with marketing (SIETI, 1978, p. 13). Frequent power cuts and shortages were also often given by craftsmen as disadvantages of electrification, indicating that reliability of supply may be as valued in small industries as in large (SIETI, 1978, p. 13).

An important unresolved problem in this research is therefore whether rural small industries--where cheap electricity could on a priori grounds be an important stimulus--can be expeditiously developed by a well-planned program that provides other key factor inputs (and necessary infrastructure) to potential entrepreneurs.

Conclusion

Rural electrification is commanding large sums of investment capital and subsidies in developing countries, on the assumption that the benefits in terms of raising living standards and economic development are commensurate. This working paper has examined scattered evidence from some rural electrification experiences, with a view to making some preliminary assessment of their success. Without more systematic studies, however, a primary focus here must be on indicating the kinds of data that should be gathered and analysis that ought to be attempted in future rural electrification programs and research, in order to better establish the relationship between rural electrification and development and provide an improved basis for policy.

Summing up

Sectoral Patterns. Benefits from electrification are related to use, and the first point that stands out is that use of electricity in rural areas is very low compared to industrialized countries or to urban areas of developing countries: geographic coverage in rural areas tends to be limited, and actual users within electrified areas are a small percentage of the population, perhaps 10 percent in many cases. Coverage and quantities used appear higher in Latin America than in Asia, with Africa at the low end. Sectorally, residential use is about a third to one-half or more of the total in most projects, and productive uses--industrial, commercial, irrigation--make up most of the remainder.

Geographic and Income Equities. In general, larger and more advanced localities are more electrified than smaller ones, and tend to be better able to reap the benefits of electrification to households, agriculture, and industry. The often small percentage of the population that use electricity in rural areas tends to be drawn disproportionately from the relatively better off, but there is evidence on the other hand that the poor do value electricity and in some cases are willing to allocate a high proportion of their income to its use. Amounts consumed are low in any event, with the predominant uses often being lighting and ironing. Appliance ownership, which largely determines electricity consumption, correlates highly with income.

Productive Uses. The most significant potential for economic development through rural electrification lies in its use in productive enterprises, in agriculture and industry. High returns to tubewell irrigation using electricity, to small as well as to large farmers, have been experienced, due to increasing cultivated area, more intensive cultivation, and changes in cropping patterns. But these benefits are clearly not attributable solely to electricity, since diesel-powered irrigation also has quite high returns.[17] Industrial benefits from the use of electricity on the other hand appear quite high as compared to alternative energy sources.

Indirect Benefits. Some of the major reasons often given in favor of rural electrification are the indirect benefits which are expected to flow from the introduction of a major modernizing catalyst into an area. These

17. Naturally, the applicability of water-lifting irrigation to rural areas is also not general, since gravity and rain-fed irrigation is possible in many areas, and groundwater appears insufficient for tubewells in others.

are difficult to measure, and it is also fair to say that little effort has been made to measure them. Two important facts must be borne in mind. First, some of the indirect benefits might be more effectively achieved through other means, and second, it is in practice difficult to separate the effect of electrification from other aspects of economic development which often accompany it. In any event, social and public uses as in schools and health clinics, for street lighting, and for commercial refrigeration that is rented to households could be beneficial to the poor in particular. It is likely that employment impacts of electrification would be positive in agricultural use for irrigation, but could be negative in industry in the absence of more general economic growth. Environmental and foreign exchange impacts are secondary and not unambiguously positive on net, but this depends largely on the fuel used for generating central station electricity. Effects on fertility and migration may be present but are probably related more to general economic development than to electrification. The impact of electrification on modernity and innovation in the countryside has probably been important in some cases; but the possible "synergistic" effects of electrification together with other productive inputs are a key question.

Costs of Autogeneration. Costs of autogeneration versus central grid electricity depend on the cost of generation, the distance of the area to be electrified from the main grid, the density of consumption, the load factor of demand, and other factors. In general, autogeneration is more expensive than the grid except for remote areas with very low and scattered demand. But many areas in developing countries are of this type, and autogeneration may still have to be used in such areas for a long time in the future. Even in electrified areas, centrally generated electricity could be more expensive than autogeneration, depending upon the circumstances: the availability of local renewable fuels is one factor. The net advantages of the grid may also be overestimated. Subsidies are often concealed, and costs to consumers and society in terms of outages and voltage fluctuations are not counted. Still, the low costs of generation of central station electricity may outweigh these considerations, especially if grid electricity is generated with low cost domestically available fuels such as hydro, coal, and natural gas, while autogeneration uses imported diesel oil or gasoline.

Costs of Alternative Energy Forms. Scattered cost comparisons for some of the major alternatives to electricity in practice in developing countries show that for households, electricity is often more expensive than kerosine for lighting but that this may be because use and quality of lighting are greater and incomes higher in electrified households. Water lifting costs for diesel engines versus electric motors are much disputed, and are very site-specific since grid costs are related to the distance from the main grid and the load. The choices of a true cost of capital and a shadow price for foreign exchange used to buy diesel are also key here. This analysis will change, too, as fossil fuel prices rise, since costs of central electricity supplies will not be afected proportionately due to cheap hydro and the large share of transmission and distribution costs in central grid electricity.

Prices and Subsidies. Prices for electricity in rural areas vary greatly, but are reported as high as 16¢/kWh in some cases, even for the grid. Subsidies appear common, especially in the early years of rural electrification, with cross-subsidies from households to productive uses, capital subsidies from other government revenues, and loans at concessional rates from international donor organizations being the most usual forms.

Effects on Production. A key question is whether these subsidies produce the desired effects, since those to households appear to benefit primarily the better off, and productive uses of electricity seem quite profitable. The availability and reliability of electricity appear more important than its cost for most productive uses, as evidenced by the use of backup generators for both irrigation and industry in rural areas. Subsidies to electricity may sometimes make little difference in production and locational decisions, particularly for new productive users, since electricity is only a portion of the total costs of using electricity, and energy costs are just a small part of total operating costs for most enterprises. For households the costs of connections and appliances can be 30 to 60 percent of the total costs of using appliances, and the share of electricity costs in total operating costs of farms and industries is in many cases around 3 to 5 percent. Once investments in appliances and connections are made, of course, subsidies will more likely influence consumption. For small rural industries, price may be more of a factor, since energy costs are a higher proportion of total costs, though reliability still is somewhat important. Other factors such as the availability of credit and marketing are probably even more crucial for small producers.

Research Recommendations

Large sums of money are currently being expended on rural electrification while lacking a clear notion of its impact on economic development. The devotion of a part of these funds to research on some key unanswered question about this relationship therefore appears justified. This working paper has based some limited conclusions on scattered data and anecdotal evidence: but the need for systematic research in this area is clear, including analysis of:

(1) Alternatives to electrification. Electrification may not be the most important need for backward areas, or for poor people in electrified areas. Subsidies to other forms of energy, to other basic needs such as food or clean water supplies or to income-generating opportunities might make more sense if the poor are the target group. On the other hand, electrification may facilitate these other goals, and the feedback effects are complex and deserving of study.

(2) Alterntives to the central grid. Using social cost calculations and examining particular circumstances will likely show other ways of generating electricity or other energy sources entirely as often more economical alternatives than has been supposed. In addition, autogeneration may be the only choice in many localities for a long time in the future, and the potential for locally available renewable means of autogeneration or motive power should be explored. The effects of rising oil prices in the future on the relative costs of autogeneration and the grid could be critical.

(3) Subsidies and effects. The true costs of rural electrification are often obscure, making it impossible to make judgments about net benefits. In particular, the effects of subsidies on use by households, by the poor, and by productive users require further definition. The relative importance of price, versus availability and reliability in production decisions, espcially needs to be explored.

(4) Impact analysis. Clearly, the important information needed in order to effectively evaluate the effects of rural electrification on economic development is the changes in standard of living, output, employment, and other ariables after electrification. This information should be collected for periods spanning several years so that the long-term effects of rural electrification can be examined. This is not the information currently being gathered in most electrification projects. Both direct and indirect benefits could be analyzed in this manner, as for many transportation projects; such an evaluation could be incorporated systematically into project appraisals. A framework for an evaluation of this sort of impacts on the poor has been proposed in a report to USAID (PCI, 1979); a broader approach is needed though to include overall effects on economic development.

(5) Priorities for electrification. Since more advanced and larger areas seem to have higher returns from rural electrification than more backward ones, should these localities therefore be electrified first, given the scarcity of investment resources in developing countries?[18] One of the clearest conclusions that emerges from this analysis is that costs, groundwater, infrastructure, appropriateness, and the availability of other inputs vary from place to place, and that there is a need for more explicit targeting of suitable areas in rural electrification planning.

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18. One Indian study (Sen Gupta, 1977) has ranked talukas (sub-districts) in one district using an index of groundwater availability, infrastructure, and backwardness, and advocates priority electrification of areas with good groundwater resources and adequate infrastructure, but fairly backward status, in order to take into account both efficiency and equity considerations.

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